EMERGENT HYBRIDITY

Cyborgs in Architecture

by

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A thesis
presented to the University of Waterloo
in fulfilment of the
thesis requirement for the degree of
Master of Architecture

Cambridge, Ontario, Canada, 2018
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AUTHOR'S DECLARATION

I hereby declare that I am the sole author of this thesis. This is a true copy of the thesis, including any required final revisions, as accepted by my examiners.

I understand that my thesis may be made electronically available to the public.

ACKNOWLEDGEMENTS

Thank you to my supervisor Philip Beesley, for being patient, thorough and tenacious throughout my writing and research of the thesis. You gave me courage to pursue the topic to its potential and at my highest ability. Your help and knowledge from the Living Architectural Systems elective, video calls, in-person meetings and your intuition to dig deeper was indispensable to the gathering and formation of it.

Thank you to my committee members Terri Boake and David Correa for their time and for giving me inspiration to continue. Both of you helped me by steering my research in a positive direction with rigour. A great amount of detail surfaced because of you both.

Thank you to Michael Fohring for taking the time to read and review my thesis. Your pursuits in architecture are inspiring and your questions push me to explore more in my future career.

Thank you to Douglas Lintula for your copy-editing services. Your encouraging comments, positive and solid feedback throughout the process of editing made a huge impact over the days leading up to its completion. Your professionalism and honest opinion provided me great freedom to push the boundaries of the document.

Thank you to Henry Ho for talking, meditating and writing calligraphy with me. The questions you asked enabled me to grasp what art is and can be. I am glad I found a way to channel our encounters into this thesis.

Thank you to Scott Proudfoot and Marc Antoine-Pepin for supporting me. To the basketball crew, Haley Zhou, Felix Cheong and Clarence Qian, y'all ended my days at school with some great exercise and laughter. Lisa Brown and Ronald Tang for making my experience at UWaterloo an amazing one. If I missed you, consider it a call for a reunion!

Thanks to my brother, sister, mom and dad for persevering with me and being part of my unconventional journey in to becoming an architect. Whether it be working out together, dragon boating or having dinner, the times spent together as a family eased my mind while writing.

Thank you to my friends Bill Zhang, Anna Tang and Timmy Cheung for listening to my thoughts in between it all. You've been in my journey since the beginning. I couldn't have done it without you guys.

Finally, thank you to Doris Li, whom would have read this. More to come.

To my mom and dad.

ABSTRACT

This thesis examines architectural test-beds as an experimental and contemporary mode of creating architecture that realizes the potential of many of the connections and complexities found in living systems. It builds on the lineage of research from the Hylozoic Ground Environments and the notion of the chthonian, embodying the potent, hidden, and essential ingredients of life.[1] From the notions of geotextiles and cyborgs, a new conception of architecture is uncovered at the scale of material compositions, wearables, and tensile structures in architecture. After a survey of precedents as well as their concepts, design processes, and cross-disciplinary inputs, the thesis concludes with the design of an interconnected human body that is, an expanded human physiology connecting body, site, and surrounding structure in the form of public space in the alleyways of the North Point Lowlands, Hong Kong. The design departs from the North Point Lowland's reclaimed and constantly rehabilitating site features to generate a coherent public space. The design proposal utilizes bifurcative qualities found in living matter, solar energy, and physiological processes to inspire a physical structure and its inhabitants. The design proposal is a co-generated physical form arising from a moment of feeling peaceful and emergent while experiencing the hybrid qualities of life in the alleyways of Hong Kong, North Point.

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01
INTRODUCTION
EMERGENT HYBRIDITY

This thesis is built upon three areas of research regarding the potential for an expanded human physiology in architecture.

The Chthonian, Will of Soil. [Fig. 1.1] New earthly, unseen, and remediating qualities are explored in the design process for creating architectural space. In the process, different interpretations of dark soils (potent, hidden, and essential ingredients of life) are considered.[1]

Living Concepts and the Vital Energy of Earth. [Fig. 1.2] Case studies and film precedents are presented that deal with specific constituents of living systems. Included are examples of architectural test-beds in living architectural systems involving geotextiles and cyborgs.

Spatial Syntax, A Resonant Gathering. [Fig. 1.3] A design project of a co-generated public space is presented based on numerous factors, including inhabitant needs, the built environment, dark soil considerations and the site itself. The project is situated in the North Point Lowlands of Hong Kong, a location deeply tied to the roots of its urban fabric. The North Point Lowlands presents a case study in which architecture is generated in conjunction with the continuing process of land reclamation, community building and the preservation of natural resources in the ongoing development of Hong Kong Island.

Together, these three areas of research provide a basis for establishing a deeper connection between human and architecture, bringing together deeply scattered and incoherent elements evident in today's 21st century society. [Fig. 1.4]

THE CHTHONIAN, WILL OF SOIL

There is a new conception of architecture, and it brings to light lively qualities of the Earth and acts in conjunction with existing urban fabrics. It is seen in the design of the Hylozoic Ground environments, and their designers act much like alchemic architects who liberate attributes of the material world.[2] They are in pursuit of the

土意 - "tou ji" **Will of Soil**
Running script in black ink by author.
土 means earth, dust, clay, local, indigenous.
意 means idea, meaning, thought, to think, wish, desire, intention.

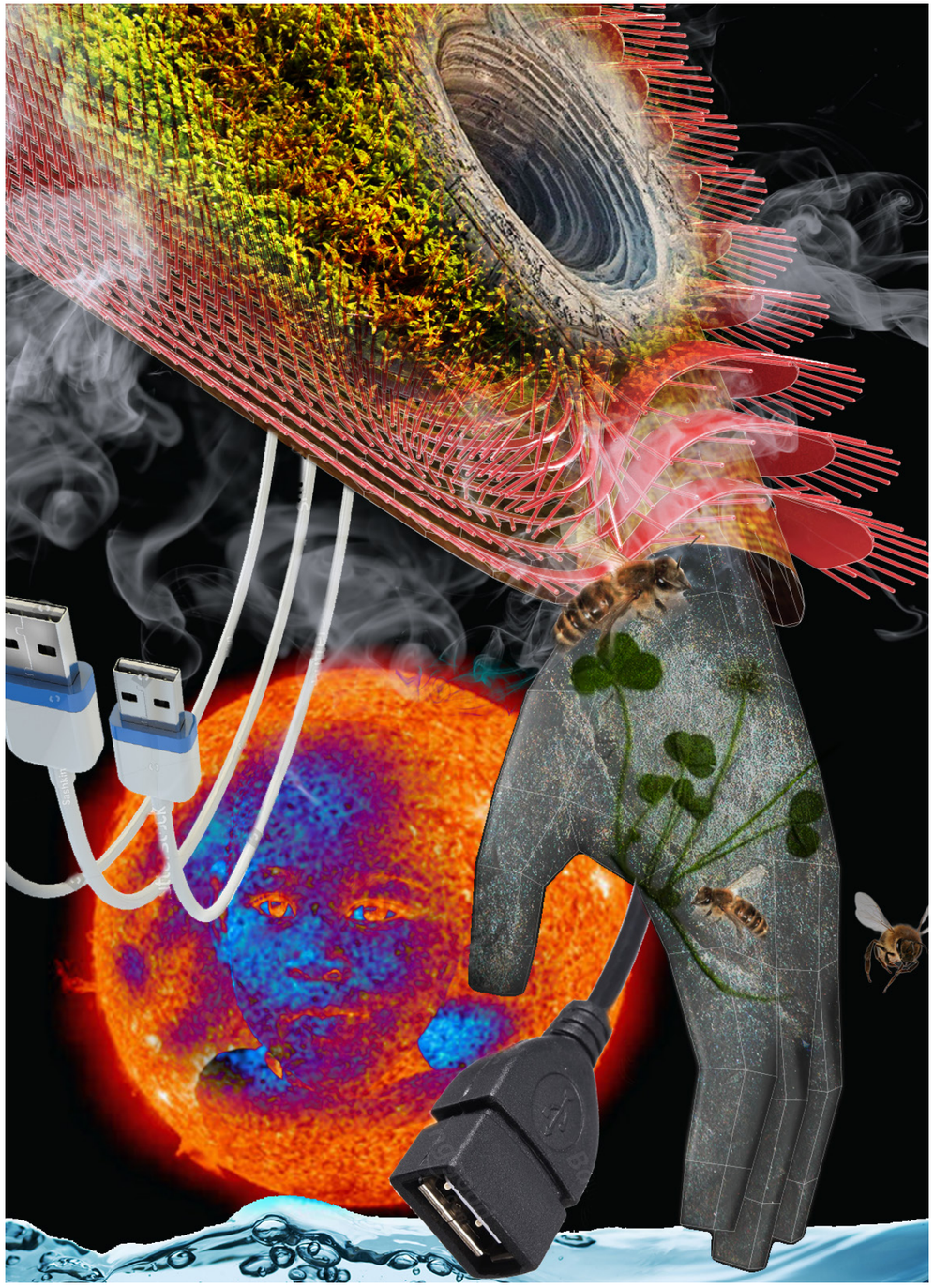
[Fig. 1.1]

地氣 - dei hei" **Vital Energy of Earth**
Running script in black ink by author.
地 means earth, ground, field, place, land.
氣 means qi, vital energy.

[Fig. 1.2]

內合 - "noi hap"
Resonant Gathering.
Running script in black ink by author.
內 means inside, inner, internal, within, interior.
合 means combine, unite, join, gather.

[Fig. 1.3]



(Facing page) New Shelters for the Body by author, photo montage (2017)

[Fig. 1.4]

chthonian, deep underground earthen layers that are waiting to surface.[3] Beesley's musings on the chthonian reveal the origins of architecture in cultural history as being attributed to primitive earthen huts that mend the wilderness.[4] From Lucretius's attention to subtle bifurcative qualities of matter,[5] there is renewed power in the notion of geotextiles. The Hylozoic Ground environments exploit this, and so geotextiles not only support the formation of synthetic layers of earth, organic growth, and take-over of land, [Fig. 1.5] but also new spatial relationships that influence cognitive, psychological, and physiological conditions of the human body, its expanded spatial boundaries.[6] [Fig. 1.6] The notion of a geotextile is an analogy applied to built structural works that communicate, from the bottom-up, with the earth and other living things to reach a generative process in design.[7] There are new design possibilities afforded from discoveries and inspirations from seemingly hidden phenomena in nature. Thus, the following research adheres to the line of reasoning guiding the Hylozoic Ground environments by uncovering similar metabolic processes and ingredients of dark soils and then proposing new types of connective systems involving inhabitants, architecture, and surrounding environments. In other words, architecture can become a geotextile, such that designed built environments are co-generated with many constituents of living matter. Architects now the have refined ability to synthesize surrounding environments with physical form, expression, and the human body to create new structures for inhabitation.

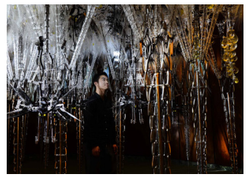
Departing from the lineage of the Hylozoic Ground environments, the proposed project at the end of the thesis questions and responds to how architects can design co-generated environments by uncovering new scales, potentials, and applications of dark soils. These new architectural conditions allow inhabitants to align with the powers of the earth more naturally. The significance of investing in that which allows the earth to exist is paramount, for without our only home, we lose the primal sensibility to live morally. This design trajectory is also evident with the works of contemporary designers, artists, architects, and collaborators who are concerned with living matter and are currently practicing this aspiration in the profession of architecture. The following research shows that there is architecture that exists in the realm of alchemy, imagination, and affective magic.

LIVING CONCEPTS, VITAL ENERGY OF EARTH

In tandem with the chthonian, a question arises: what kinds of dark soils directly influence the human body? [Fig. 1.7] The design proposal reveals that they could create crucial connections with the earth and influence sociopolitical issues important today. Thus, there is potential in the notion of the cyborg, an interconnected body, working together with new constituents of living systems, new material design processes, and material influences. It is important to note that several constituents of living systems are often not associated with classical understandings of architecture.[8] Today, living architectural systems lie in the realm of physics, chemistry, and biology and so this thesis recognizes the potential of cross-disciplinary influences on the profession of architecture. There are physical architectural test-beds, experimental and

Haystack Veil, Maine, Philip Beesley Architects Inc. (1997)
Haystack Veil is the construction of synthetic ground and the building of hybrid layers of artificial soil.

[Fig. 1.5]



Sentient Chamber, Washington, D.C., Philip Beesley Architects Inc. (2015)
According the Colin Ellard, the Human Experience stream leader at Living Architecture Systems Group, Sentient Chamber allows him to observe changes to one's psyche, body and immediate surroundings.

[Fig. 1.6]

(Facing page) New Shelters for the Body by author, photo montage (2017)

[Fig. 1.7]

contemporary modes of creating architecture, that can realize the potential of many connections and complexities found in living systems. For example, movements observed at the scale of atoms become inspiration for architectural space; and so, Lucretius called these movements the clinamen, the unpredictable swerve of atoms.[9] Its transposition in architecture would yield living qualities, and one could say that these are electromagnetic forces that create patterns, radiuses, orientations and directions of shapes, lines and masses in nature that are then used to influence design.[10, 11, 12] Jenny Sabin Studio saw the potential of proto-parametric fabric surfaces to directly capture these subtleties in Lumen's architectural surfaces. In this case, textiles, through warp and weft, could generate extremely sensitive, light-weight, and parametrically influenced material surfaces.[13] [Fig. 1.9] Another example of cross-disciplinary pursuits in architecture is seen with Paz Gutierrez and her research with BIOMS (Bio Input Onto Material Systems). Her research is about materials designed at the scale of their chemical compositions to become ecologically adept.[14] [Fig. 1.9] From the arrangement of materials at the nanoscale, these materials can save energy, biodegrade, and have low embodied energy just like phenomena observed in natural materials. Furthermore, the thesis presents research that prioritizes interrelating material networks in construction and design processes to embody, as well as give full potential to, earth's energy.[15] [Fig. 1.10]

Close-up detail of Lumen's surfaces [Fig. 1.8]

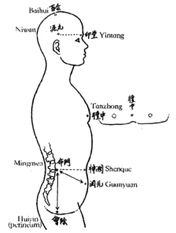
BIOMS research into mixture sucrose PMMA panel protoypes [Fig. 1.9]

(Below) Proposed canopy section inspired by sun patterns of spring, the flow of heat energy, rhythms of the human body and tensile structures formed by electromagnetic forces of the site [Fig. 1.10]

[Fig. 1.11]

The Vitruvian Man, Leonardo da Vinci, 1490

[Fig. 1.12]



Eight meridian points, of small circulation flow, flowing along points counter clockwise in image

SPATIAL SYNTAX, RESONANT GATHERING

Architecture has always been influenced by the human body. Space was designed in proportion to the human body to reach a higher state of consciousness. After all, it is due to the belief that the human body was created in the image of God.[16] Today, architects design for a changing twenty-first century society, such that the human body is no longer a predefined entity.[17] However, in the 15th century, designed-built environments in Western architectures are believed to have allowed one to become more alive or, better yet, to fully realize the potential of life on earth. Leonardo da Vinci's Vitruvian Man (1490) embodies the relationship between bodily proportion and surrounding space. It displays two superimposed bodies, one with arms raised and legs apart, the other with arms open and legs together. [Fig. 1.11] At the same time, the body is inscribed within a perfect geometric circle and square, which raises a connection of divine order in the universe with the human body, proportion in harmony with spatial geometry. Moreover, traditional Chinese medicine understands the human body as a flow of qi 氣 through meridian points, objective entities in the human body that correlate to viscera.[18] Through meridian points, there is a primary flow of qi 氣 responsible for vegetative capacity to function as an organ or tissue.[19] The flow of qi 氣indicates the presence of a living system, so tending to meridian entities and external influences can change its flow.[20] [Fig. 1.12]

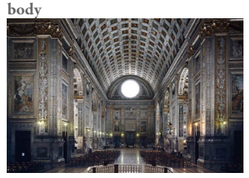
Together, Renaissance architects, as well as builders in the Eastern world of the 15th century, practised and designed an architecture that reflected a relationship between spatial composition and the human body to attain synchronicity with the rhythms of divine order.

Historically, architectures for spiritual worship were particularly grand examples that exercised a relationship between the built environment and the divine. Architecture in this case would not only provide shelter from the elements, effectively keeping the exterior out, the interior protected, but also guide methods of spatial arrangement that enabled the body to attain a deeper level of spiritual consciousness. As seen in Leon Battista Alberti's Sant 'Andrea, (1472-90) [Fig. 1.16] in Mantua, Italy, this structurally monolithic 15th Century church presents the belief that the human body, created in the image of God, could reflect divine and cosmic order within a building's plans.[21] The church's plan is ordered and arranged to reflect proportions of the human body, with the human head in place as the altar, the torso as the crossing, with a tower allowing light to enter, the arms as the transept, and legs and neck as the nave. [Fig. 1.17] There were certain cosmological relationships embedded with the construction of these buildings, bringing their inhabitants closer to God.[22] In Eastern architectures, buildings like the Temple of Heaven revealed a spiritual platform for communication with the heavens.[23,24] The Circular Mound Altar consists of a circular

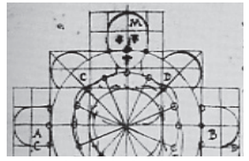
(Left) Canopy and column rendering at dusk **[Fig. 1.13]**

(Centre) Wearable energy harvesting suit deployed in alleyway **[Fig. 1.14]**

(Right) Tensile column structures inspired by natural rhythms of the body **[Fig. 1.15]**



Interior view within Sant' Andrea (1472-90), Leon Battista Alberti **[Fig. 1.16]**



Hu(man) inscribed within architectural drawings **[Fig. 1.17]**

[Fig. 1.18] **Circular Mound Altar, 1530, built by the JiaJing Emperor and rebuilt in 1740**

[Fig. 1.19] **Interior view of reading space and book stacks of the Bibliothèque Nationale de France, 1854**

platform on three levels of acoustically fit marble stones. Used by the JiaJing Emperor to pray for favorable weather, this spatial arrangement amplified spoken thought to the sky.[25] Material quality and a tuned positioning, where the emperor would stand, presented a harmonious platform. [Fig.1.18] In the same tone, architecture of the Beaux Arts period reflected a decorative style of floral patterns and fauna. Architects like Pierre- Francois- Henri Labrouste designed buildings such as the Bibliotheque Nationale Paris during 1858-68. The reading room, comprised of thin one-foot diameter columns, and terracotta domes, allow for ample light to enter. The architecture embodies functional and decorative aesthetics found in nature ,such that the columns were as sensibly and elegantly thin, just as a tree would be, to perfectly support its own weight and allow one to read under it, as in a forest.[25] [Fig. 1.19]

The examples mentioned above reveal deeply engrained meanings in architectural space and artistic sensibilities in history. They indicate relationships between the human body, nature, and the divine, with spiritual space for prayer, by aesthetically enhancing one's connection to the divine realm or by injecting the natural sensibilities with technology and the forest. Sedentary architectural spaces form much of our built environment today, however, its consistency in beauty and elegance is not. Today, building types of the suburban ideal, pencil tower cubicle farms and shopping centres alike, are simply, rigid mediators of the environment. So,

it is necessary to transcend Vitruvius's notion of firmitas, the imbued sense of firmness, solidity, stability, strength and materiality.[26] There is potential for architectural space to do more by mediating human experience with concepts explored in this thesis. These include different scales and proximities of material qualities and interactions, prosthetic enhancements to the body, ubiquitous and anticipatory information, artificial intelligence and automation, self-maintenance, the use of sound, and distancing the mind from the body. Beesley refers to the latter of the dichotomy as dew drop spaces, spaces that are comprised of interiors and exteriors, contrast, reduction and equilibrium.[27] [Fig. 1.20] [Fig. 1.21] Architects can regain agency in the profession and propose connective spaces and surfaces on top of existing urban fabrics. [Fig. 1.22]

Given the beauty of the architecture of historical antiquities, we should continue to experience the said architectural spaces and allow them to influence our bodies. So it is important to now ask: what can the architecture of tomorrow do for the earth and its people? What are the conditions in which architecture can allow for the remediation of the human body and its surrounding environment as if the earth were an expanded human physiology functioning in harmony with new sensitivities for the 21st century?

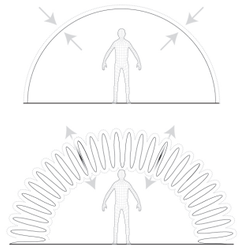


Diagram of dewdrop vs snowflake architectures. The dew drop speaks of interior and exterior environments, contrast and reduction. The snowflake is about inclusion.

[Fig. 1.20]

Interior view of Oceans, Nuit Blanche , Toronto City Hall, Philip Beesley Architects (2016)

[Fig. 1.21]

[Fig. 1.22] **(Below) Aerial view of proposed canopy membrane engendering the possibility of interaction in a seemingly inert and decomissioned portion of North Point, Hong Kong**

A PROPOSAL IN NORTH POINT, HONG KONG

After a survey and an analysis of precedents, as well as synergizing concepts, design processes, and cross-disciplinary inputs, the thesis concludes with a design proposal for a public space to be integrated within the urban fabric of Hong Kong as a type of land remediation. It continues the process of land reclamation on the island and fosters a way for people interact with the site on a multi-communicational basis. The project is meant to be a thoughtful addition to the North Point Lowland alleyways, attempting to provide a moment of synergy between the study area and its inhabitants. The goal is to create a more inclusive, connective, and sensitive space, functioning as a healing fabric accomodating citizens and existing communities. The design proposal is achieved after an investigation in tensile structures. It realizes the potential of various qualities of spring-time and the flow of heat throughout the day in the built environment. Other site influences include the perception of electromagnetic forces throughout the site by translating these attractions and repulsions into patterns, radiuses, orientations, and directions of shapes, lines, and masses. The act of perceiving these forces is embodied and expressed in a sculptural form. The design proposal is the formation of a new type of architectural membrane that brings to light a perceivable combination of self and surroundings that approaches an unrestrained form of being.

ENDNOTES

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4. Ibid.
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6. Beesley, Philip. "Introduction, Liminal Responsive Architecture, Soil and Protoplasm." In Hylozoic Ground: Liminal Responsive Architecture, 13. Cambridge, Ont. Canada: Riverside Architectural Press, 2010.
7. Ibid.
8. Three architectural values resonate with Vitruvius: firmitas, utilitas and venustas. More evident and widely accepted today, is the notion of firmitas. However, there is great potential to explore the possibilities of architecture to transcend the notion of firmitas and into a new conception of architecture. See Beesley, Philip. "Dissipative Models: Notes Toward Design Method." In Living Architecture Systems Group White Papers, edited by Roushan, Ala. Final ed., 7. Waterloo, Ontario: Riverside Architectural Press, 2016.
9. See Introduction, and references to the clinamen, Beesley, Philip. Kinetic Architectures & Geotextile Installations. Waterloo & Toronto: Riverside Architectural Press, 2007 & 2010.
10. Ho, Henry. "Tai-Chi Calligraphy." 2018. http://isartgallery.com/tai-chi-calligraphy/.
11. Beesley speaks of an experience during meditation as he feels the earth around him. He is an observer of the earth and recounts the meeting of the earth and the sky, the feeling of blending and becoming a part of the forest, sun and light disappearing in the distance and how an eclipse on the moon passes in time. These experiences are what Beesley refers to as the clinamen - the name Lucretius gave to the unpredictable swerve of atoms. In other words, clinamen, refers to an encounter of zero and the slightest divergence from it. See Tangent p27; Philip. Kinetic Architectures & Geotextile Installations. Waterloo & Toronto: Riverside Architectural Press, 2007 & 2010.
12. 氣 or "Qi" etymological explanation for the word, in its written traditional form, is steam 气 arising from rice 米 as it cooks." It is well known that within the human being there are vegetative patterns and are regulated as part of the homoeostasis of the body. One vegetatively induced functional state passes over into the next, and all these countless vegetative processes together form a functional vegetative continuum which on the whole leads to a great deal to the homoeostasis of the body. If disease occurs, it is due to the blockage of "qi" flow, the block of vegetative functional transitions. Thus, it can be said that qi is the autonomous movements or functional powers found in nature; Xia, Ying, 1955-, Guanghong Ding, and Gen-Cheng Wu. "Chinese Medicine as a Model of System Biology: Diagnosis as the Foundation of Acupoint Selection." In Current Research in Acupuncture, 624. New York: Springer, 2013.
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23. Stokstad, Marilyn. "Ming Dynasty, Architecture and City Planning." In Art History Portable Edition: A View of the World Part Two, edited by Touborg, Sarah. Vol. 3, 839. Upper Saddle River, New Jersey: Pearson Education, Inc., 2009.
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02
LIVING CONCEPTS AND ARCHITECTURAL TEST BEDS

(Above) **Lumen, MoMA PS1, YAP, New York, USA, 2017** **[Fig. 2.1]**

Jenny Sabin Studio is researching to further the design of buildings by integrating certain natural elements within the context of conventional design approaches. The studio questions how natural organisms, as studied in biology, integrate with their surrounding environments. This becomes a valuable precedent in designing for the built environment as it addresses how multiple living things can become a coherant whole. Their research points to methods that, from the bottom-up, integrate a vast number of site variables, such as sun attributes, the movement of people, or aspects of the human body to magnify the potential of their interactions in design. Lumen by Jenny Sabin Studio seeks inspiration from textiles, as a proto-parametric and generative approach in constructing architecture, and also from the cross-pollination of knowledge between biology and architecture, making Lumen a paradigm for architects to consider constituents of dark soils.

MOMA PS1, Y.A.P.

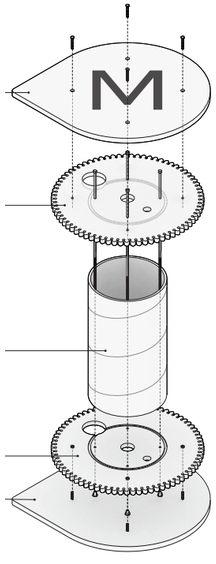
[Fig. 2.1, Fig. 2.2, Fig. 2.3] Lumen by Jenny Sabin Studio was selected as the 2017 winner of the Museum of Modern Art and MoMA PS1's Young Architects Program for a design proposal of a temporary, outdoor pavilion that provides shade, seating, and water whilst working within guidelines that address environmental issues, including sustainability and recycling. This project also supports Warm-Up, a platform for DJ's and musicians in MoMA PS1's concrete bordered courtyard. Further, it will serve 40,000 visitors day and night over the course of the hottest, sunniest, and most bustling months in the city. It does so with co-produced textile canopies, tensile structural supports, water cooled micro-climates, and robotically assembled and recyclable seating.

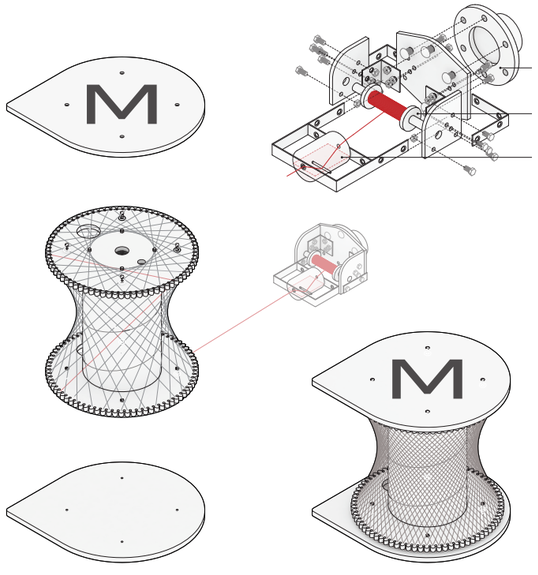
LUMEN'S ARCHITECTURAL COMPONENTS

The courtyard is covered with two architecturally scaled canopies made of knit, light-absorbing textiles. A tensile canopy topography distributes forces to the concrete walls where it is anchored inplace. The canopy consists of hundreds of cells called knit windows and cones that provide shade and a swaying dynamism below. Visitors play, touch, and sift through the soft structures where they can

(Left) View of knitted deep windows and textile canopy from interior **[Fig. 2.2]**

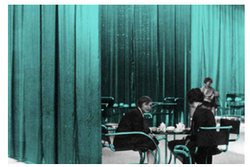
(Right) Aerial view of MoMA PS1's concrete courtyard, textile canopy, and structural tensile towers **[Fig. 2.3]**





[Fig. 2.4] **(Centre) Axon drawings of robotically woven recycled and cnc'd spool stools that were constructed in-house**

[Fig. 2.5]



Historical textile artists and printmakers include Anni Albers, Gunta Stolzl, and Lilly Reich, who have integrated tapestries, vertical curtains, codes and patterns with modern architectural space-making. Image above is the interior of the Silk and Velvet Café, a collaboration between Mies and Reich.

also sit and relax. There are two 35-ft. tall tensegrity towers that support the larger canopy and a 24-ft. tall tensegrity tower for its smaller canopy. A misting system is strung throughout the canopy, providing a cooled micro-climate in specific areas of the courtyard. Visitors can cool down from the summer heat or sit and hang out. Complementing the canopy structure, the towers, and misted micro-climate zones are recyclable, thread-spool stools that are robotically assembled and tensioned with photo luminescent micro-cord. The stools are marked with unique letters made of hydro-chromic ink [Fig. 2.4] and can be rearranged to convey messages within the misted zones of the courtyard. A beautiful space is generated from the bottom-up, influenced by people, the site, and the best in local, global, live, and electronic music every weekend. At the end of the day, bioluminescent fabrics interwoven within the knit windows and cones create an illuminated space that is occupiable well into the night.

TEXTILES

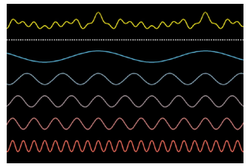
Textiles makeup the principal material system of Lumen. A textile is not only a physical material but also understood as a specific element in craft making and designing. Sabin's early lineage of research in textiles suggests its roots are in the

Bauhaus's textile workshops in the 1930s, which were predominantly occupied by women.[1] [Fig. 2.5] The practice of weaving is said to be fundamental to parametric design, since weaving is influenced by color, pattern, line, and surface, thus forming one of the earliest modes for producing complex material surfaces.[2] Taken beyond its metaphorical meanings as expressed in the patterns and colours prevalent in 1930s modern art, it exists as a complex, scalable material process in architecture.[3]

In Lumen, weaving, mathematics, and music are directly correlated, such that weaving can be described as a simple binary system with the capacity to produce complexity like that described by a Fourier series. [Fig. 2.6] For instance, sin- and cosine waves, warp and weft: both add together, producing complex frequencies and surfaces. Jean-Baptiste Joseph Fourier (1768-1830), a French mathematician and scientist, more or less, initiated an investigation in quantum mechanics with the Fourier series.[4] The Fourier series can be applied in describing quantum phenomena ,as pursued in the field of physics today. Louis de Broglie (1892-1987) in his PhD thesis in 1924 proposed that all matter has wave-like properties, and from Fourier's transform method,[5] one can decode and understand complex frequencies of sound as individual components of simple waves. Following this, physicists could understand quantum mechanics as theorized by Heisenberg's Uncertainty Principle[6] (1927) (Unschärferlation or Unsharpness Relation). This theory states that every particle can be observed by its position and momentum, much like sound and frequency. Thus, the Fourier Series in design allows for hidden and subtle phenomena found in nature to permeate architectural material processes like those found in living systems.[7] In architecture, site parameters, inhabitants, and the ecosystem are capable of becoming decoded and then interwoven in the production of bottom-up architecture, integrating an immensely sensitive material surface in the process.

NIKE FLYKNIT COLLECTIVE

Lumen's woven designs incorporate data extracted from inherently invisible phenomena of our daily surroundings. Jenny Sabin drew inspiration from her collaboration with Nike's Flyknit Collective, which logged essential data from athletes to robotically knit together enhanced shoe uppers. The Nike Flyknit Collective is the combined research of programmers, engineers, and designers, including Jenny Sabin over a span of four years. A single thread is all it takes to begin construction of a shoe upper with enhanced structure and durability. Flyknit technology, compared to traditional leather or polyurethane shoe material, provides improved flexibility, breathability, and weight reduction, all in one material. This material system allows shoes to be highly customizable to the sizes of athletes and type of activity undertaken. The mode of production also reduces material waste of the traditional cut-and-sew process by an average of 60 per cent, saving many kilos of material from reaching landfills.[8] [Fig. 2.7] This, in turn, inspires the tensile windows and tubular structures that comprise the entire canopy, resulting in a co-generated textile steered with human bio-data. The fabrics were machine-knit with "WHOLEGARMENT"

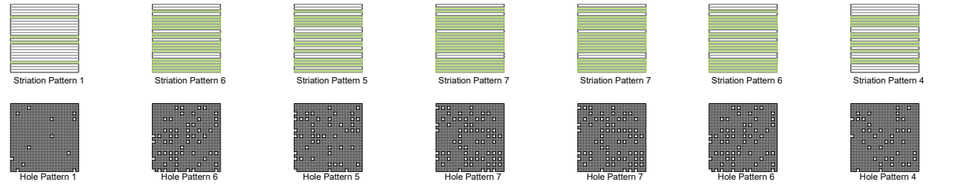


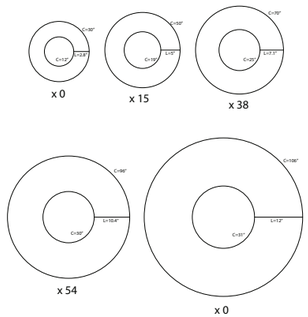
Shown above, the yellow wave is a complex frequency with alternating air pressures over time. A Fourier Series is the represention of the yellow complex function as a sum of simple sine waves seen as the colored waves below it.

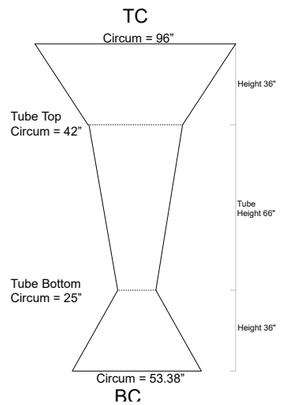
[Fig. 2.6]

Nike Flyknit technology used to construct this shoe upper

[Fig. 2.7]







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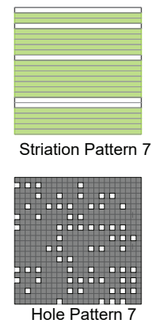


by Shima Seiki with the knit fabrication process customized to incorporate patterning that translates human bio-data into hole and striation patterns of fabrics.[Fig. 2.8] [Fig. 2.9] The materials include three responsive fibres: photo luminescent, solar active and reflective. With the weaving of different types of fibres, each textile can respond to different types of stresses and strains, external influences like light and water absorption, or reflectivity and color. Counter to expectation, the holes knitted into Lumen's surfaces provided additional structural support, thereby corresponding human bio-data with architectural form. Sarah Bonnemaison reinforces the notion of textiles by stating that its potential can be drastically exploited in immersive environments and at scales of the human body.[9] By adapting clothing, furniture, and the built environment, textiles can become communicative devices that facilitate personal expression, as well as multi-point communication between individuals and groups.[10]

PART-TO-WHOLE RELATIONSHIPS

Textiles feature part-to-whole relationships, complexity building, and emergent behaviour, thereby privileging textiles as a biological process in nature. Architecture informed by biological models in nature is not new. Advancing from Buckminster

(Previous facing page, top) Machine woven cells and units that compose Lumen's fabric canopy made with WHOLEGARMENT elements fabricated by Shima Seiki

[Fig. 2.8]

(Previous facing page, bottom) Programmed patterning that is read by sewing machine; striation patterning and dots correspond to individual stitch type

[Fig. 2.9]

[Fig. 2.10] **(Below) Site section, including space for Warm-Up festivities and Lumen's canopy and tensile towers**

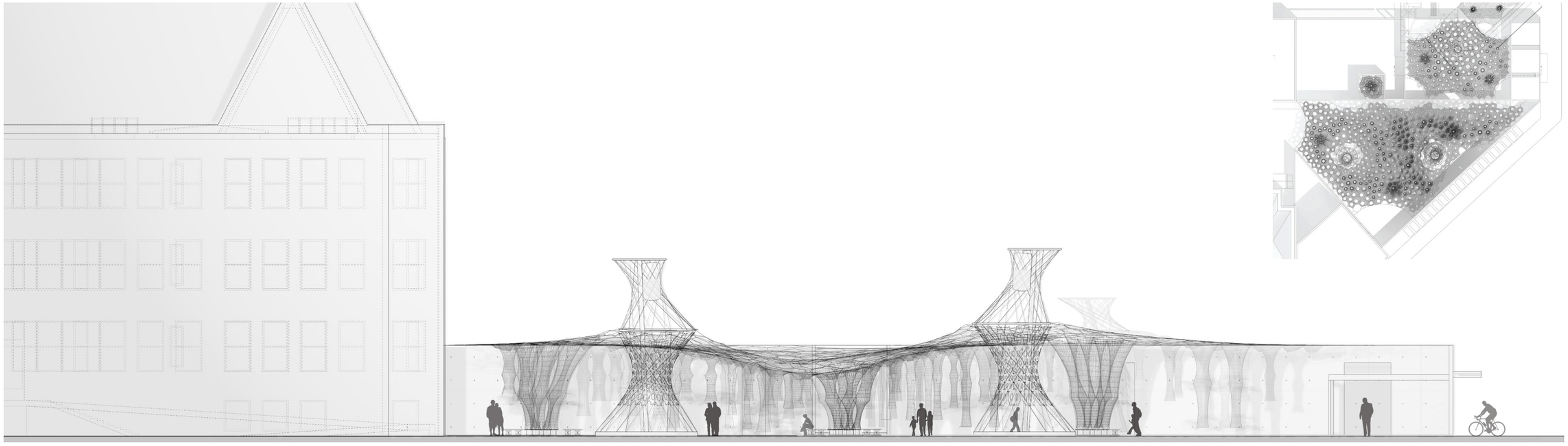
[Fig. 2.11]

LabStudio's Branching Morphogenesis project (2008) utilized 75,000 zip-ties to scale and materialized force networks of five different time frames

Fuller's notion of biomimicry where crystals and rock structures inspired the production of his crystalline structures, the notion of biosynthesis[11] proposes that functions and cell behaviours in biology can influence a context-driven architectural form with additional layers of information that approach natural living systems. [Fig. 2.10] Biological cells interact with their environment, indicating deep interior logics of nature. A study of cell networks by Donald Ingber, a bioengineer, proposed that there are mechanical forces exerted over individual molecules, cells, whole tissues, organs, and organisms.[12] His study proliferates into a model of ecosystems and their influences over spatial environments at the scale of individual cells and perhaps living architectural systems.

CELL BEHAVIOURS: NETWORKING

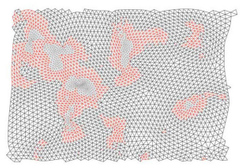
Jenny Sabin and Peter Lloyd Jones of LabStudio examined endothelial cells (EC) to illustrate context-cell networking and at the same time, context-driven architectural form.[13] ECs are cells that line blood vessels and the lymphatic system in the human body. Their project, Branching Morphogenesis [Fig. 2.11], studied ECs as the basis for forming an architectural scale membrane. While studying ECs, they observed their sensitivity to fluid shear stresses that trigger changes in a cell's shape. To



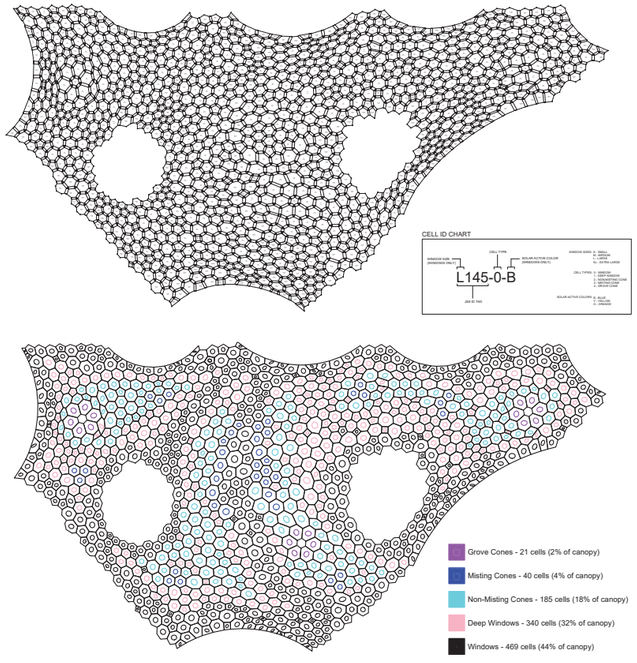
study ECs they observed them in-vitro, in other words, test-tube-like environments. An extracellular matrix (ECM) of interlocking mesh of fibrous proteins and polysaccharides was simulated so that the area outside of cells could be used to help observe and determine causal and networking relationships of dynamic cell systems in real time. Thus, ECMs mapped changing positions of ECs so that seemingly invisible force networks exerted on each cell were made tangible over multiple time sheets.[14] [Fig. 2.12] The movement of ECs discovered in Branching Morphogenesis presents a pedagogical shift in understanding, such that biologists and architects can observe motility and cell movements in living systems from temporal attributes.

ARCHITECTURAL FORM: CELL SITES

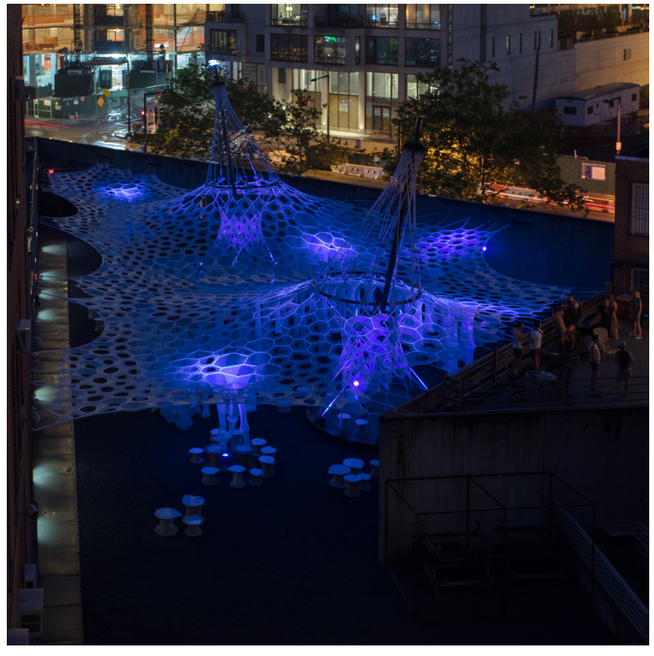
Following on the capabilities afforded by observing cells in ECMs, a digital algorithm called a Voronoi Shape Diagram, named after Georgy Voronoi (1868-1908), can be used to represent proximity information about a set of objects or points.[15] In Lumen and Branching Morphogenesis, the translation of knit-windows and EC sites respectively [Fig. 2.13] allow for the construction of an architectural surface that is embedded with invisible force networks. Each site of ECs is translated with a ready-made zip-tie with zip-tie joints at each normal to compose



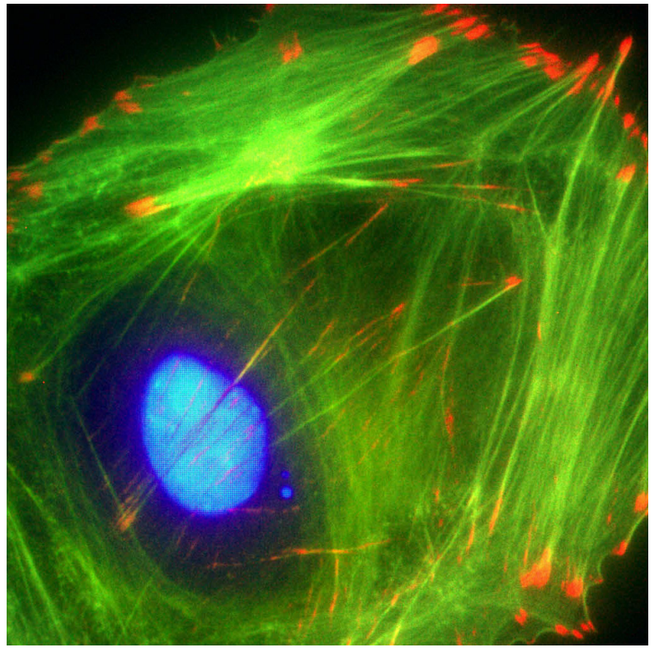
[Fig. 2.12] **Time slices are moments of endothelial cell activity cultured within a specialized extracellular matrix that can suppress or promote networking**



[Fig. 2.13] **(Left) Production plan diagrams used by fabricators to identify and locate knit elements to form a larger fabric canopy**



[Fig. 2.14] **(Centre) Exterior view showing canopy illuminated at night; lighting is programmed to highlight music, and also strategicaly positioned around the courtyard while on digital timers to simulate day-to-night sequences**



[Fig. 2.15] **(Right) A network of molecular filaments that act in tension extending from extracellular space to the DNA via cytoskeleton. Cytoskeletons give cells its shape and help organize cell parts while also providing a basis for movement and cell division**

its architectural surface. Lumen's canopy is very much a light catcher as well as an externally influenced surface of seemingly invisible forces such that its Voronoi Shape Diagram canopy provides it with a tuned materialization of densities of bodies, heat, and sunlight.[16] Much like each site of ECs mentioned above, each canopy knit window represents a site that embodies the solidification of a parametrically and externally influenced parameter like an organism such that it is influenced by the sun, as well as its site, materiality, program, structure, and physical participation. [Fig. 2.14]

LUMEN AS ORGANISM

Building on the coherence of topological and material components mentioned above in Lumen, one can parallel Lumen as an organism with coherant tissue that includes its surounding microenvironments. Lumen's tensile force network can be expressed as sculpturally representative forces in cell networks. Buckminster Fuller believed that tensegrity structures contain a system of energy-creating space that is not static.[17] It is possible to see Lumen as a cytoskeleton of a cell. [Fig. 2.15] At the nano-scale, tensile filaments within cells mechanically aid in shape deformations to produce observable changes to the cells.[18] Cells sense and feel chemical forces with the aid of different proteins that are responsible for sending signals out from or within

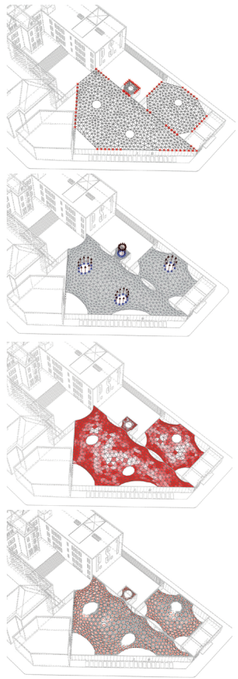
the cell, structuring and anchoring and separating tissues within an ECM. These tensile filaments are in constant communication with their surroundings and enact the functionality of the genome, the central motor of cells, with all the information needed to build and maintain an organism.[19] Lumen's three tensile towers are the primary structural supports designed to communicate with the surrounding canopy structure. [Fig. 2.16] They allow flows present within the courtyard space to permeat across it. Moreover, a similar analogy of the influence of seemingly insivible force networks can be seen in pre-stressed foces that act in conjunction with their intended loads. Similarly, the tensile towers in Lumen are designed with foces that act in conjunction with their inhabitants and the charged spatial environment that it spans. A tensile structure has the capabilities to communicate with its entire environment much like the cytoskeleton of living cells, giving shape and coherence.[20] [Fig. 2.17]

LUMEN'S KNIT FABRICS

The complexity of human bio-data incorporated in Lumen's knit fabrics, consisting of part regular yarn and photo-luminescent yarn, reveal interior logics associated with human physiology. The human bio-data corresponds to three types of yarns used: photo-luminescent yarn, which absorbs UV light and glows in the absence of it; solar active yarns that change colour in the presence of bright sunlight, and reflective threads that provide bursts of light. The threads can amplify the hidden structures of the unseen human bio-data, allowing the textiles to become strategically paired with external influences such as the time of day, the amount of artificial or natural light, and the light given off by inhabitants. The timed revealing of colour, the production of colour, or the reflection of it, is, in a way, the production of structural colour[21] such that, in addition to color pigments, structural colour can, at a nano-scale, interfere with visible light to produce a visual phenomenon found in butterfly wings, peacock feathers, or soap bubbles.[22] The structural colour of butterfly wings at the nano-scale indicates a geometric and structural influence on the observable production of colours that manipulate light and create patterns of beauty.[23] This notion of a nano-to-macro generated patterning due to each individual knitted thread is central to the production of Lumen's bioluminescent surfaces. [Fig. 2.18] [Fig. 2.19] [Fig. 2.20]

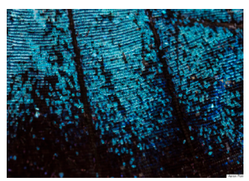
(Facing page) Axon and orthographic drawings of tensile tower bars with platform where people can stand and gather. Steel was fabricated by Jacobsson Carruthers, and are secured in tension by ropes and canopy net

[Fig. 2.16]



[Fig. 2.17]

Form finding logics of canopy structure. Top to bottom, anchor points located, gravity and material loads applied, solar study info and cell shape and finalization

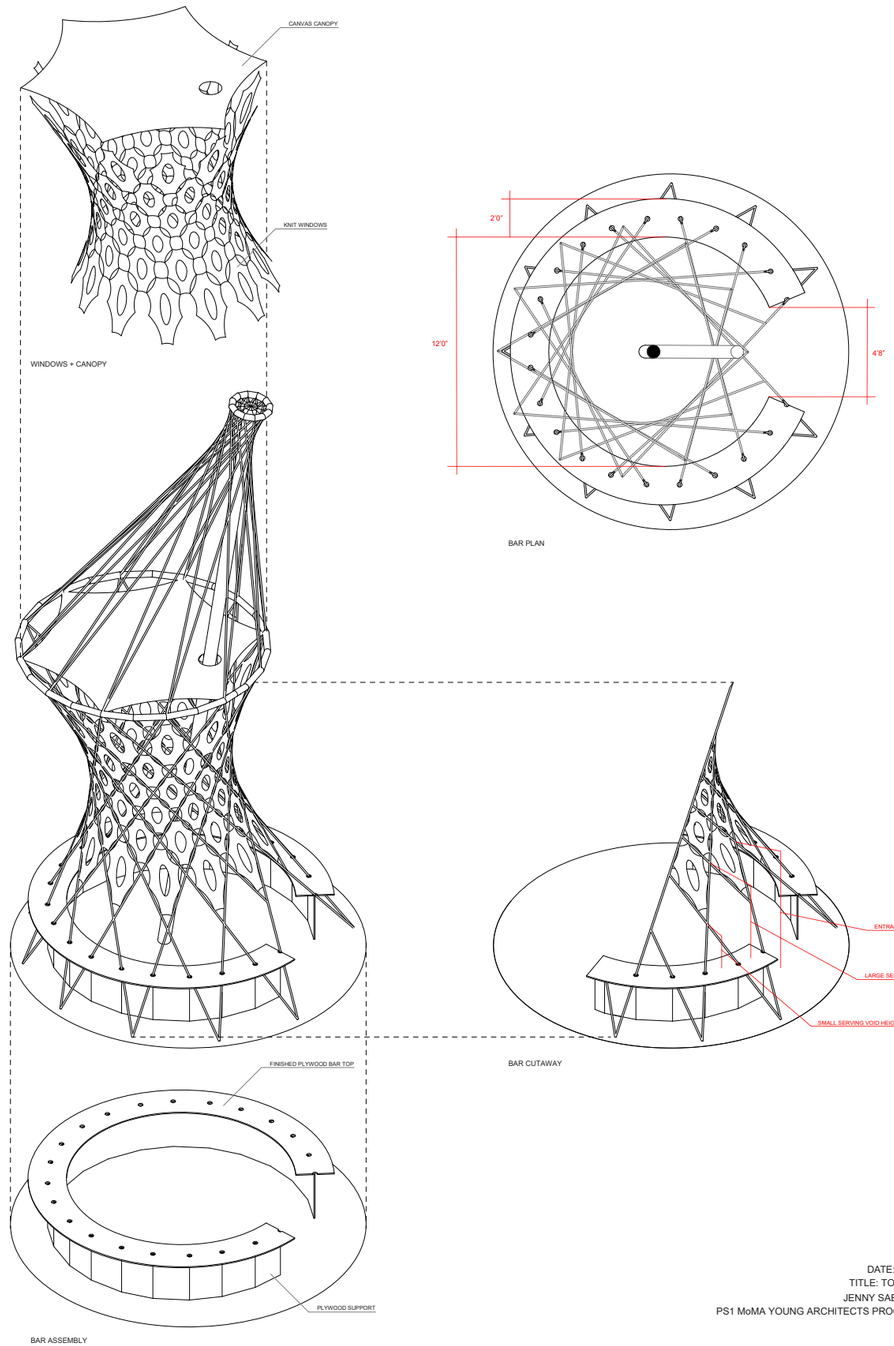


[Fig. 2.18]

A microscopic view of a butterfly wing composed of nanostructures that bounce light back at the blue wavelength

(Left) Interior view at night of smaller 24-ft. tower. UV and black lights shine onto tower and canopy

[Fig. 2.19]



A PEDAGOGICAL ADVANCE

The cross-pollination of knowledge between biologists and architects by LabStudio initiated dialogue that created pedagogical advances twofold. The first advancement is in the architectural craft of constructing a context-driven architecture from inspirations in cell behaviours. The second advancement can be seen in the datasets of biologists, where spatialization and visualization of data presented biologists with new realms of inquiry. Cell behaviours such as their movements could be named, and a spatial form language could begin to be recorded as a language to inform biologists in their research. LabStudio's research in, for example, the surface design of mammary glands as a model of architectural connectivity[24] indicated a contextual information that influences surface structures of mammary gland cells. This, in turn, could aid architects in the design of shell or spatial structures with interior structural behaviours.[25]

TRAJECTORY

MoMA PS1's 2017 Young Architect Program winner, Lumen, is a project charged with many of the hidden logics that approach living systems in nature. The orchestration of space in conjunction with MoMA PS1's courtyard, summer festivities such as Warm-Up, its textile material system, and resonating knowledge between biology and architecture produces a space that generates complexities found in nature. In other words, it can be said that Lumen is a construction of a geo-textile, a space that not only reinforces the grounds that it encompasses, but engenders the possibility of life. We can see Lumen helping to create a world where its constituent parts allow architects, designers and scientists alike to approach constantly improving acts of composting, experiencing and creating. From Lumen, one can inherit a sense of optimism from collaboration with other fields as well, allowing one to design space with renewed sensitivity to a changing 21st Century environment. [Fig. 2.21]

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19. Ibid., p.40.
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25. Ibid.

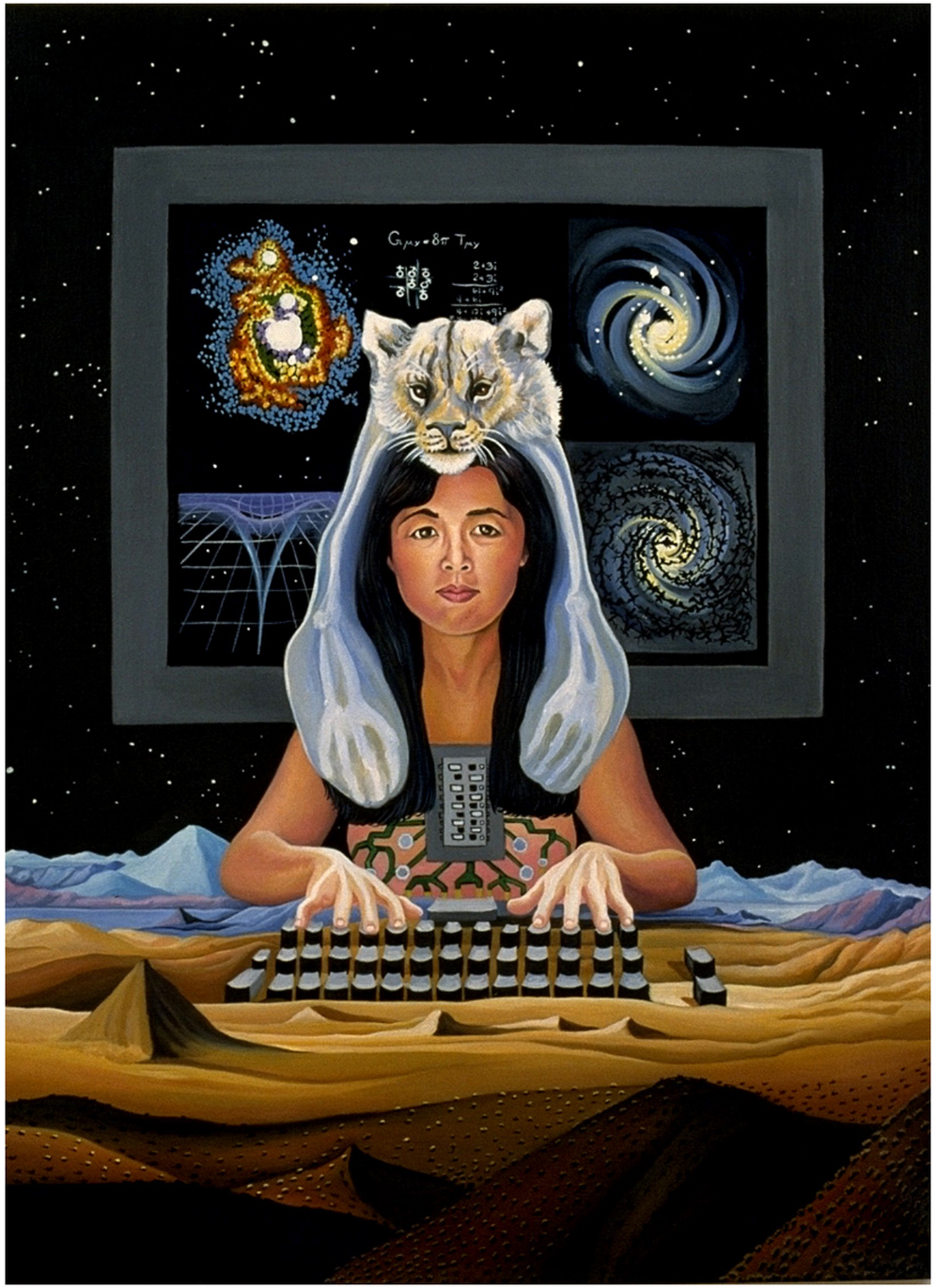
[Fig. 2.20] Interior view of canopy looking up, photoluminescent threads activated

[Fig. 2.21] Aerial view of canopy during the day with different knit cells types and openings visible

03
THE AUTONOMOUS & THE CYBORG

CY • BORG - noun [sahy-bawrg]
a: An expanded body occurring mechanically and/or bio-mechanically with enhanced abilities.
b: A person whose physiological function is aided by or dependent upon a mechanical or electronic device.
c: Short for cybernetic organism.

In 1960, Manfred Clynes and Nathan S. Kline coined the term cyborg as a being with both organic and biomechatronic body parts that guide and assist in a journey through outer space.[1,2] Its definition can be readily understood as a biomechanical robot body or body parts that cybernetically serve the human brain, such that its parts enact functions of human physiology like breathing, muscular maintenance, and cardiovascular control.[3] Donna Haraway suggested that Clynes' and Klines' notion of the cyborg can be seen in an entirely new light in that the constituent parts of cyborgs are neither mechanical, electronic, nor organic.[4] Rather, Haraway saw cyborgs as being without preconceived notions of class, race, and sexuality.[5,6] Haraway's definition saw cyborgs through a psycho-social lens, such that cyborgs are blurred and reinvented beings who no longer function within a hierarchal society, an unsuppressed being of the world.[7,8] Similarly, Bill Mitchell applied the notion of the cyborg in the context of architectural space making. He theorized that structures of human relationships will change in the digital age; urban realms would become soft cities, and spaces of gathering would become electronic agoras.[9] A short time later, Haraway would posit that her cyborg definition must evolve from a psycho-social standpoint of the unsuppressed human to the cyborg- chthulucene,[10] a more inclusive, responsible, and Earthly being crucial to the survival of the planet.[11] The notion of



(Facing page) Human, cyborg: Human-computer/ artist/ writer/ shamans/ scientist, Lynn Randolph (1989) **[Fig. 3.1]**

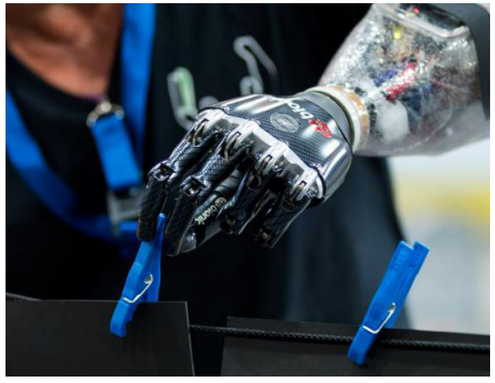
the architectural test-bed approaching living systems realizes these aspirations.[12] Moreover, there is potential in another scale of the architectural test-bed conjured by the notion of the cyborg mentioned above. The cyborg (a cybernetic explorer of space,[13] unshackled citizen,[14] interconnected scholar[15] and creature of the wild[16]) can be consolidated as a set of knowledge and methods for understanding the mysteries of human life. The notion of the cyborg is a spatial and architectural relationship between humans and universe, nature and people, to achieve a harmonious and complementary realm. This relationship can be explained in three different facets of interaction with surrounding space. Firstly, cyborgs can interact with surrounding space by coupling their body with artificial extensions such as prosthetic limbs, breathing devices, and vision correctors, etc. [Fig. 3.2] They can also interact with surrounding space using their psyche, which can be seen with the use of brain wave controllers, media, or programmed air. [Fig. 3.3] Finally, another type of interaction with surrounding space exists wherein the body's surroundings consist of oscillating amplifications and regulations by wearable devices including micro- and nano- structures that allow users to engage with various elements of their environment.[17,18,19,20][Fig. 3.4] In essence, the cyborg is an autonomous body.[21]

THE MACHINE FOR LIVING

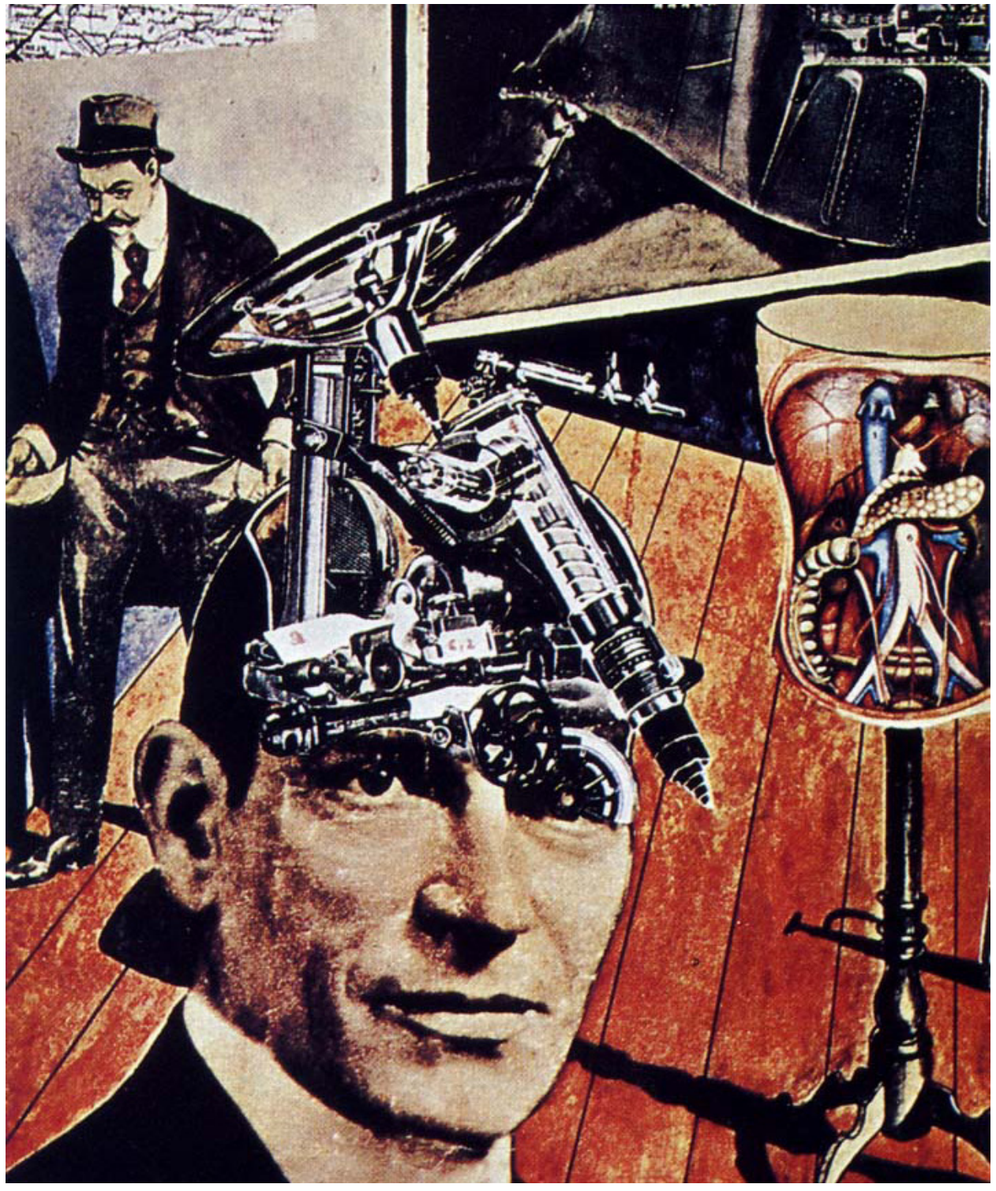
The notion of human interaction aided by artificial extensions is not new, as previously introduced in Clynes' and Klines' cyborg definition. It can be seen in architectural and costume design of the modern era.[22] This notion was pursued by R. Buckminster Fuller and Le Corbusier.[23] The *Dymaxion House* (1933) was designed for specific inhabitants and programmed spatial functions as an extension of the body. This notion was defined by norms, types, and standards so that space could also be reproduced, duplicated, and mass-produced.[24] Modulated and economically efficient spatial compartments allowed Fuller to pursue a *Universal Architecture* (1932) that can provide living space to anyone

(Left) Powered Arm Prosthesis Race, Cybathlon (2016), ETH Zurich/ Allessandro Della Bella [Fig. 3.2]

(Right) Brain-Computer Interface Race, Cybathlon (2016), ETH Zurich/ Allessandro Della Bella [Fig. 3.3]



(Facing page) Tatlin at Home, Raoul Hausmann (1920) [Fig. 3.4]



and anywhere.[25] *Dymaxion House* is a mobile house that adapts to nomadic lives of people by incorporating specific spatial dimensions that simplify quotidian tasks.[Fig. 3.5] Similarly, Le Corbusier envisioned cities with primary infrastructural and service routes such that a town would have machine-like qualities.[26] The city, as well as human body, could be regulated and controlled in terms of traffic flow and movement respectively. He applied these organizational understandings to city planning and architectural design. Efficient flows and patterns of movement could be securitized. These pursuits would result in Le Corbusier's manifesto of the *Five Points of Architecture* (1926)[27] and *Guiding Principles of Town Planning* (1925), which described standards forimproved quality of living and city functioning. [Fig. 3.6]

THE TECHNOLOGICAL BODY

Oskar Schlemmer designed costumes that changed the appearance of the human body so that it could be camouflaged within the political beliefs of the era.[28] Schlemmer's costume designs transformed the wearer's body into socially and technologically enlightened beings. His costumes incorporated basic three-dimensional geometry, as worn in his ballet production, the *Triadic Ballet* (1922). [Fig. 3.7] The designs were non-representational and geometric forms of the human body. Schlemmer and other prominent artists at the time, like Kazimir Malevich (1878-1935), [Fig. 3.8] communicated their art work with meta-physical representations of life on Earth.[29] It can be said that these geometrically formed costumes, in Sclhemmer's ballets, produced an agreeable life view with its audience, by transcending human form into simple forms to illustrate all of life's necessities.[30] This

(Left) Dymaxion House (1946) construction section **[Fig. 3.5]**

(Centre) Circulation Types, Le Corbusier **[Fig. 3.6]**

(Right) Oskar Schlemmer's Triadic Ballet Costumes (1922) **[Fig. 3.7]**

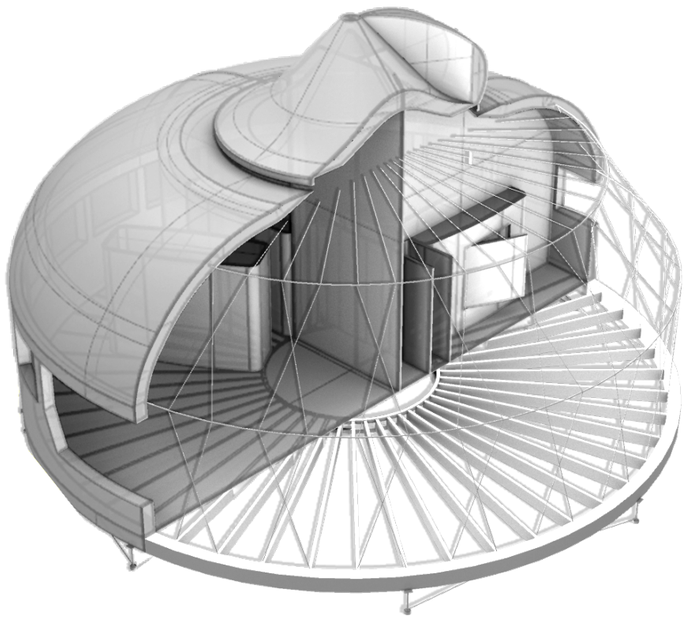
[Fig. 3.8]

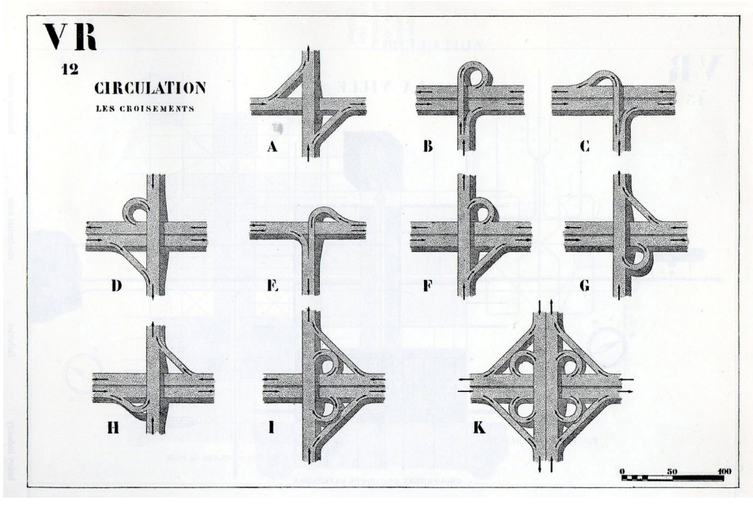
Airplane Flying by Kazimir Malevich (1914). The supremacy of pure feeling or perception, the Airplane Flying is a surface that is given life through spatial configuration.

political anxiety, stabilized by avoiding religious references, reinforced Schlemmer's costumes and works. They became socially and technologically liberating costumes and artworks for the people of the era.

PERSONAL BUBBLES OF THE TWENTIETH CENTURY

During the mid-Twentieth Century, there was growing anxiety due to the proliferation of suburban housing. This initiated discourse that responded with new kinds of interaction between the human psyche and surrounding space. The resulting architectural designs consisted of new public spaces and highly personal spatial designs. Archigram aspired for social interaction unimpeded by the built structures of the past by creating projects with mega-structures and large communication nodes.[31] Archigram's *"Walking City"* (1964) and the *"Plug-in City"* (1964) [Fig. 3.9] introduced transportable environments, time capsules, in buildings and reconfigurable spaces, all of which could be plugged into a city. By so doing, the spaces were not location dependant, and mega-structures of these machines were devoted to continual circulation and expanding boundaries of inhabitable spaces. This was accomplished with variable structures, mobile buildings, and information networks to move beyond traditional urban lifestyles.[32] The large-scale communication terminals created a space to gather, meet, and experience variable media within their spaces.[33] The latter half of the Twentieth Century saw wearable architecture influenced by heightened consumerism, nomadism, and individualism.[34] The wearable architectures seen in Haus Rucker Co.'s pneumatic air structures,[35] [Fig. 3.10] Michael Webb's *Suit-a-loon* (1967), [36] [Fig. 3.11], and Reyner Banham and





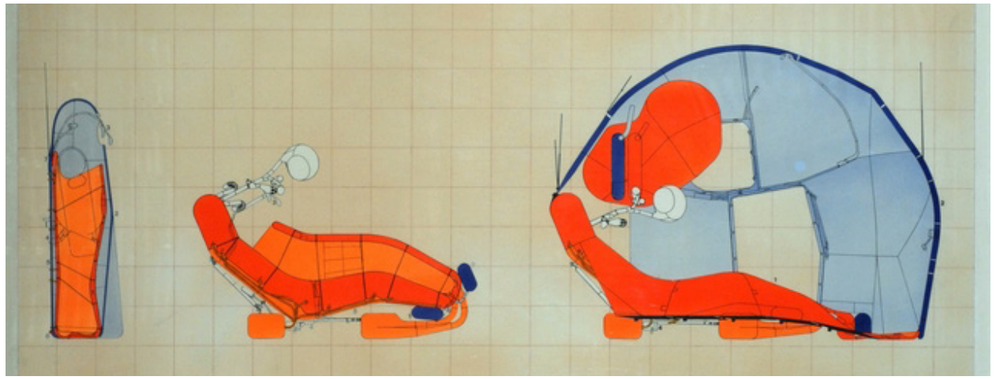
Francois Dallegret's *Anatomy of a Dwelling* (1965) [Fig. 3.12] totally disregard the suburban ideal of a personal villa.[37] Rather, these visions were mobile and nomadic homes packaged for inhabitants such that space was now a highly individualized personal climate. Space was now a temperature-regulated environment with a thin membrane encapsulating different air mixtures for new feelings in spaces.[38] Similarly, Michael Webb's *Suit-a-loon* offered mobility compared to the traditional suburban house. With a skeletal support system, the building would also carry appliances and personalized apparatuses for entertainment.

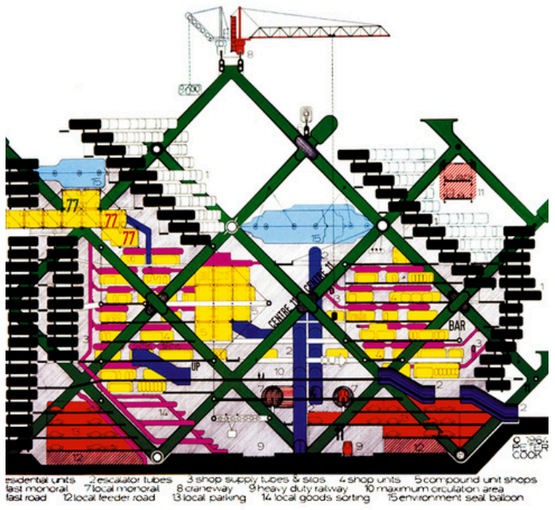
NEW MATERIAL INFLUENCES OVER THE BODY

The last set of precedents indicate materials that can generate oscillating amplifications and regulations of data or environmental elements that hold new potential for architecture. These new materials exist at different scales of influence in not only architecture, but also over the human body. They also provide new capabilities for architects and designers to design ecologically adept materials[39]

(Left) Typical Section, Plug-In City, Archigram (1964) **[Fig. 3.9]**

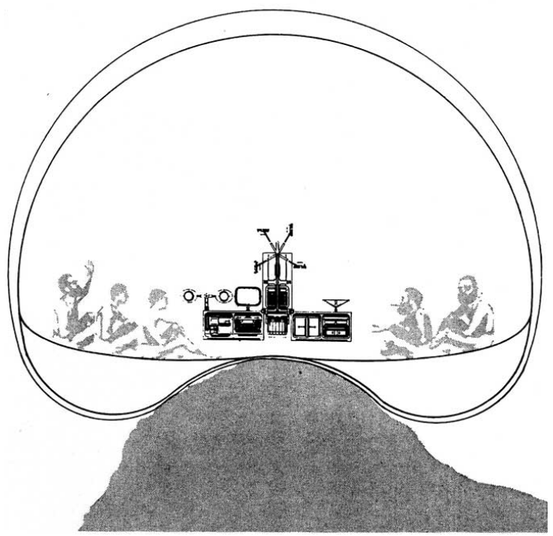
(Centre) Laurids, Zamp and Pinter with Environment Transformer (Flyhead, Viewatomizer and Drizzler)(1968) **[Fig. 3.10]**

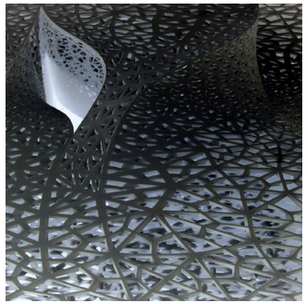


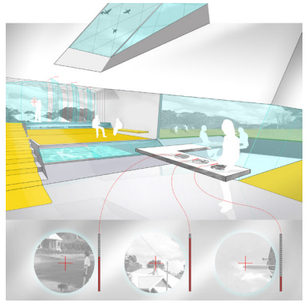


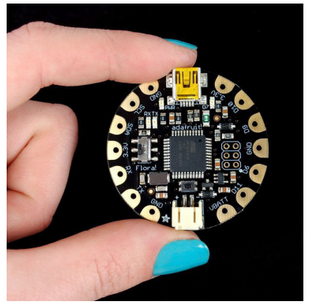
[Fig. 3.11] (Above) Michael Webb's Suit-a-loon (1966) featuring deployable suit and entertainment system. The suit can also connect to other suits for a gathering space.

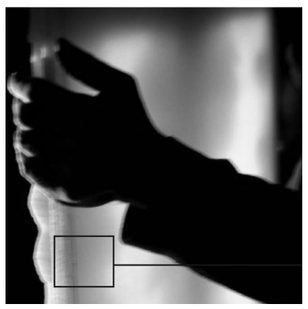
[Fig. 3.12] (Below) Reyner Banham and Francois Dallegret's Anatomy of a Dwelling, illustrating the bare bones of dwelling; consists of membrane wall, and HVAC system for climate control.

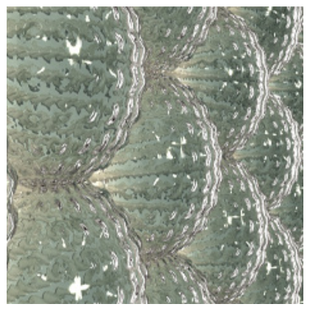


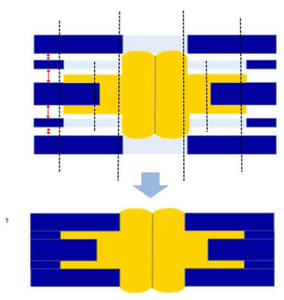












along with their inherent material networks that far outperform traditional materials,[40] allowing for the formation of new human physiological,[41] and meta-physical connections to Earth.[42] We can see new material influences in architecture in several examples such as IwamotoScott Architects' *Jellyfish House* [Fig. 3.13], Faulders Studio's *Chromogenic Dwelling* [Fig. 3.14], and Joel Sander's *Mix House*. [Fig. 3.15] Furthermore, new scales of material influences over the human body can be seen in Lucy Orta's deployable clothing [Fig. 3.16], Adafruit Industries' and Leah Buechley's wearable architectures [Fig. 3.17], and also active outdoor gear. [Fig. 3.18] Finally, the research of Paz Gutierrez's BIOMS presents unseen connections to living systems at new scales of physical intervention. [Fig. 3.19] [Fig. 3.20] [Fig. 3.21]

[Fig. 3.13] (Top left) Rendered skin detail of the Jellyfish House (2006). Image displays the mutable layered skin or deep surface that mediates internal and external environments. It deforms in thickness locally for geometric, structural, visual, and mechanical performance.

[Fig. 3.14] (Top centre) 3-D Printed model of Chromogenic Dwelling (2005)

[Fig. 3.15] (Top right) Mix House by Joel Sanders Architects (2006). Image displays the control centre of the house, capable of managing the sensory experiences of each room.

[Fig. 3.16] (Centre left) Lucy Orta's Refuge Wear - Habitent (1992-1993)

[Fig. 3.17] (Centre)Circuit Playground by Adafruit Industries; a development board with microprocessors that are Arduino-compatible for DIY electronics projects

[Fig. 3.18] (Centre right) Active outdoor gear with backpack, sleeping bag, clothing, shoes, accessories, etc.

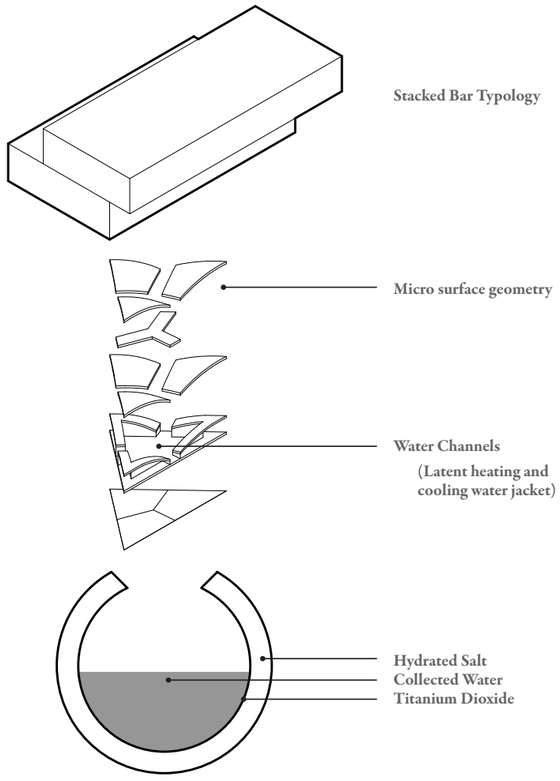
[Fig. 3.19] (Bottom left) Paz Gutierrez's BIOMS research of polymethyl-methacrylate (PMMA) and agricultural waste mixtures

[Fig. 3.20] (Bottom centre) Paz Gutierrez's BIOMS research of photocatalytic optofluidic networks created by multiple layers of integrated photocatalytic reactors

[Fig. 3.21] (Bottom right) Paz Gutierrez's BIOMS research of reversible self-actuated thermo-responsive pore membranes

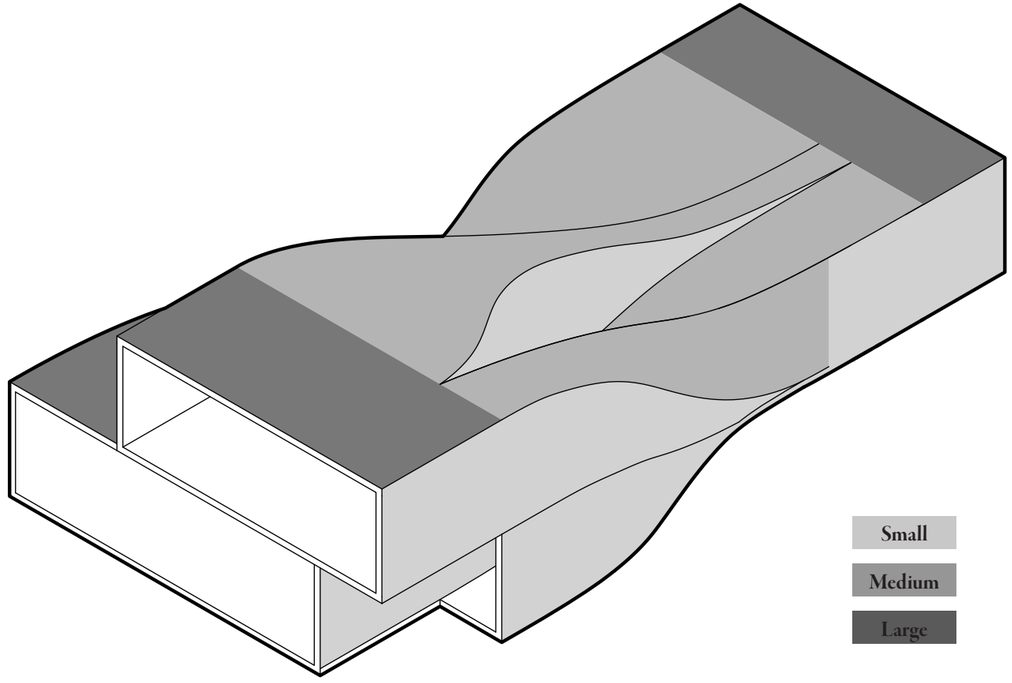
MUTABLE AND LAYERED SKIN

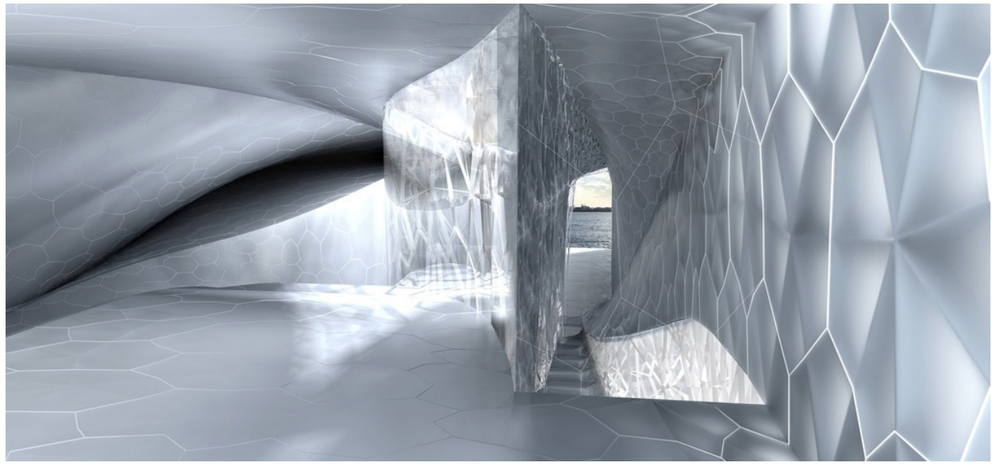
The *Jellyfish House* (2005-06) by Iwamotoscott Architecture establishes a strong site relationship by constantly filtering contaminated water, polluted air, and green house gases around the skin of the building by the process of photocatalysis: titanium dioxide panels absorbing ultraviolet radiation from sunlight acting as a disinfecting agent by oxidizing cells of microorganisms. [Fig. 3.22] This process, in turn, changes its external and internal appearance in accordance with the performance of water filtration. The building regulates the amount of surface run-off from rain and uses it to supply inhabitants, while returning it to the environment. [Fig. 3.23] There are cavities that compose the surface of the building and catch and filter water with a chemical reaction that takes place between UV light and its material system, while a titanium dioxide coating emits a blue hue to indicate the perceptual performance of the building. [Fig. 3.24] [Fig. 3.25] Situated in a designated toxic site, the *Jellyfish House* ubiquitously remediates the environment while also sheltering inhabitants.[43]



(Left) Water and air filtration diagram of material components and geometry the Jellyfish House **[Fig. 3.22]**

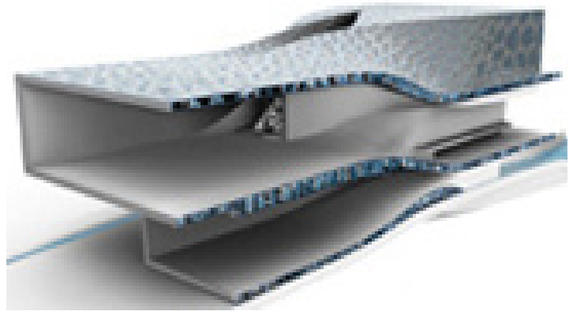
(Centre) Diagram of multi-layered surface geometry; darker areas of diagram indicate high amounts of water collection and lighter areas indicate less **[Fig. 3.23]**





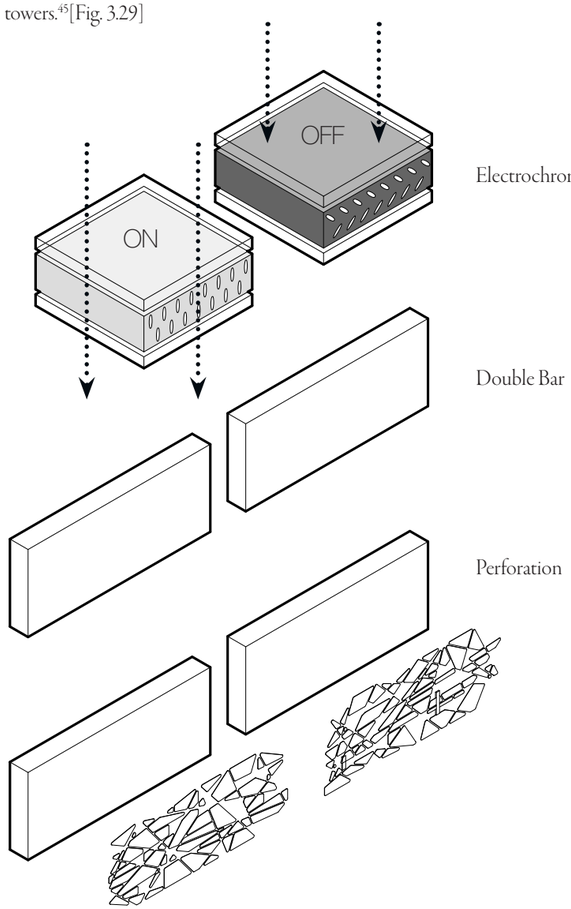
[Fig. 3.24] **(Above) Interior rendering of Jellyfish House with glowing water filtration cavities denoting the active filtration of surrounding water**

[Fig. 3.25] **(Below) Rendered building section illustrating geometric relationship to surroundings**



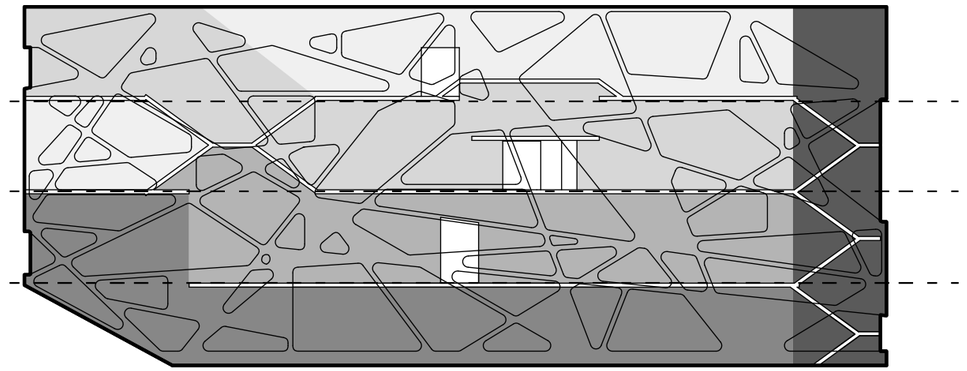
URBAN CAMOUFLAGE:

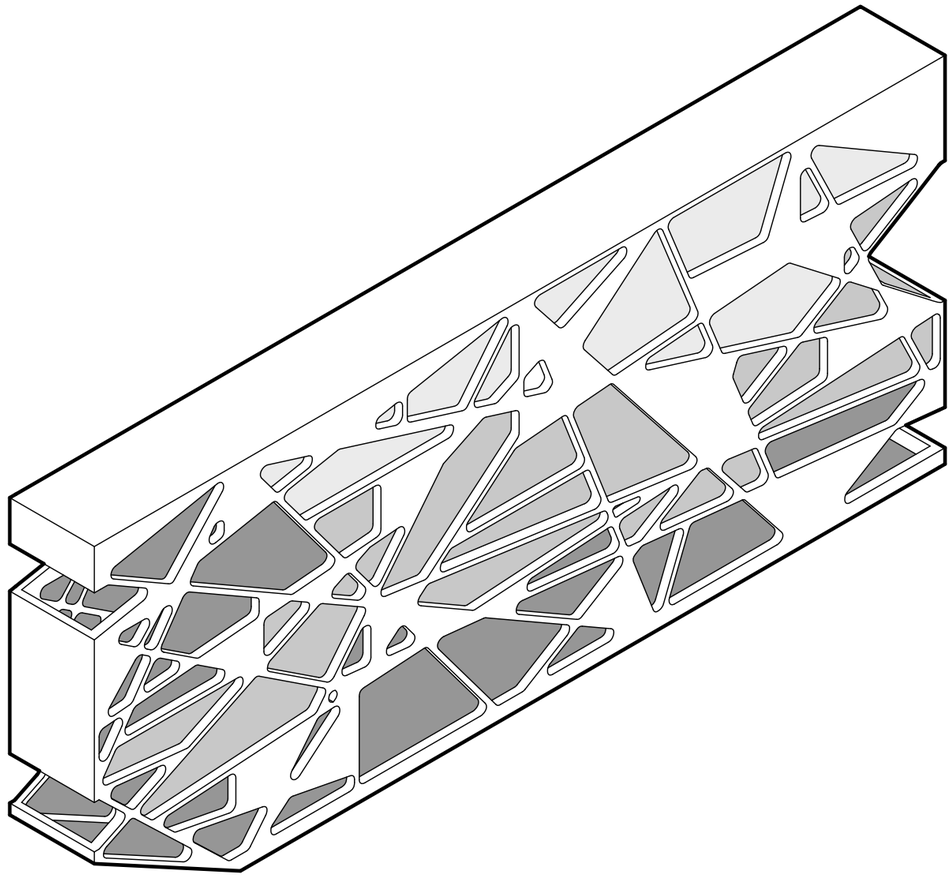
The *Chromogenic Dwelling* designed by Faulders Studio offers the notion of urban camouflage, so that inhabitants can alter the appearance of their surrounding spaces. Inhabitants can react to climate and control privacy and blend the internal organization of their home, while at the same time displaying an altered visual appearance to the exterior. [Fig. 3.27] The *Chromogenic Dwelling* is a four-storey apartment building in a typology of two thin bars at roughly 4.25 metres wide by 43 metres long and 18 metres tall. Situated in Octavia Boulevard, San Francisco, Ca., the *Chromogenic Dwellings* each house three units of residential apartments with shops and a coffee bar at street level. The building is constructed with a cast-in-place concrete structure to allow for varying sizes of window openings with electro-chromic fenestration.[44][Fig. 3.26] The build provides a high degree of shade control for the entire building with graduated shading; privacy for inhabitants, as well as a source of identification of each room; and a disguised internal organization of building elements by creating an abstracted appearance of a unit. [Fig. 3.28] Thus, urban camouflage can produce new types of spatial organizations such that the ability to disguise the internal organization of buildings removes the visual monotony of towers.[45][Fig. 3.29]



(Left) Electrochromic glass, typology and perforation diagram of the Chromogenic Dwelling (2005) by Faulders Studio **[Fig. 3.26]**

(Centre) Urban camouflage: disruptive patterning system **[Fig. 3.27]**



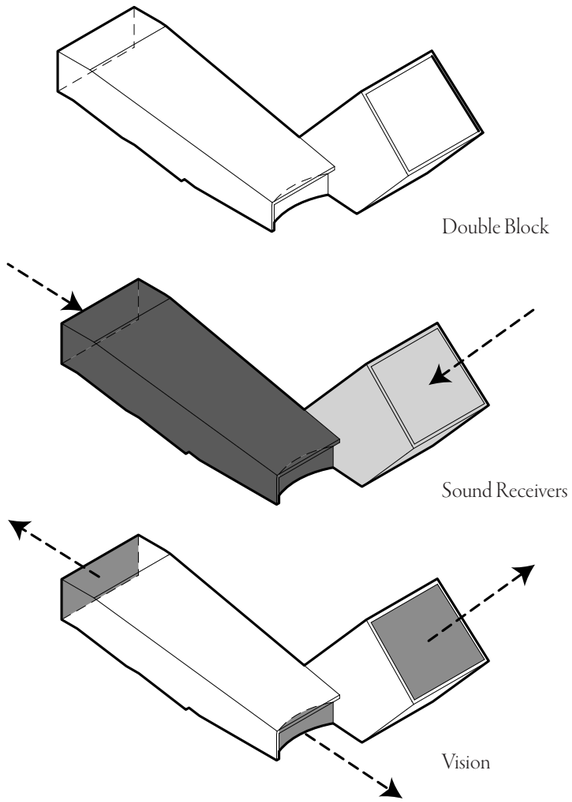


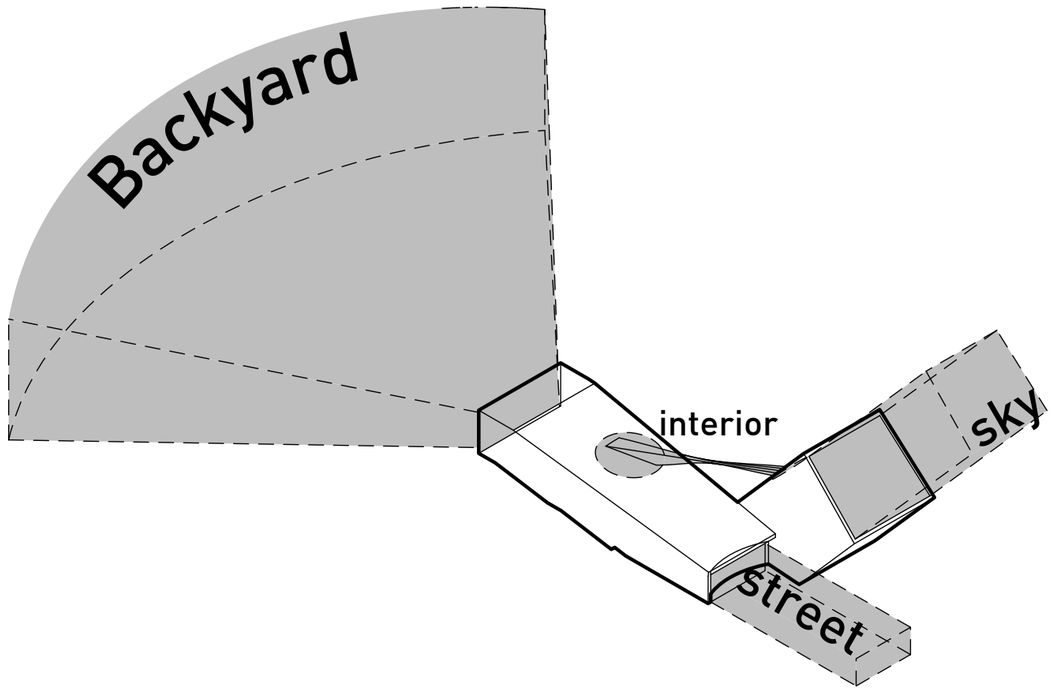
[Fig. 3.28] **(Above) Section of traditional slab arrangement and interior, camouflaged by electrochromic fenestration**

[Fig. 3.29] **(Below) Exterior rendering of Chromogenic Dwelling**

AUGMENTED SENSORY PERCEPTION

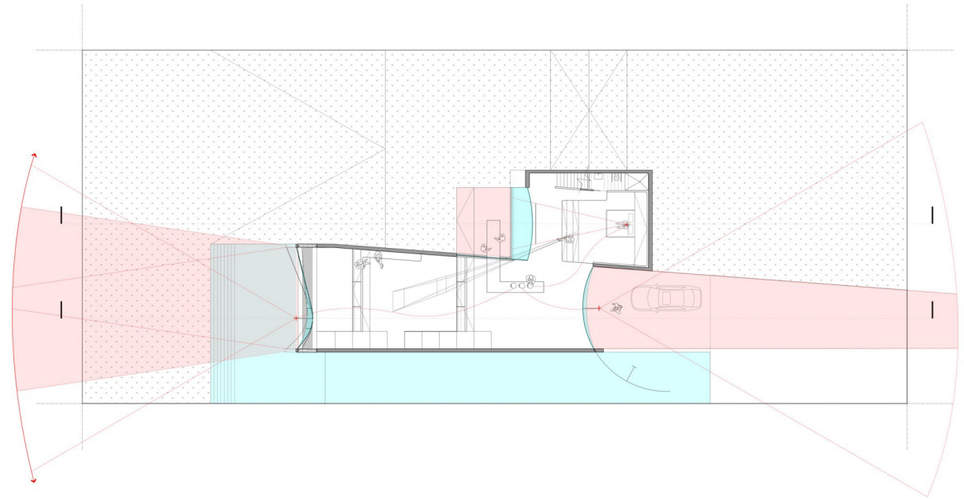
The *Mix House* inhabitants experience extended senses of hearing and vision. With the use of a reinterpreted picture window, inhabitants can become immersed within the spaces of their backyard, front yard, and immediate sky above the dwelling.[46] The reinterpreted picture window generates a new type of connection between architectural space and nature. The *Mix House* takes the form of a double block typology with two audio receivers for the exterior and three visually augmenting windows. [Fig. 3.30] Through a swivelling window projecting towards the backyard, a window framing the street and a window framing the sky, traditional perception is broadened with audio-visual devices. [Fig. 3.31] [Fig. 3.32] The *Mix House* empowers the dweller with a greater connection to the exterior. With the use of audio receivers and image-capturing software, the inhabitant has control over noise and vision over their surroundings. With the potential to tune visual and audio sensitivities, exterior surroundings can become virtually filtered to the inhabitants liking. The picture window creates a visual and audio link between the living room and backyard, the kitchen and the street, and the bedroom with the sky.[47] The renewed pictures window produces a new connection between architectural space and exterior environment. [Fig. 3.33] The traditional divide between interior and exterior





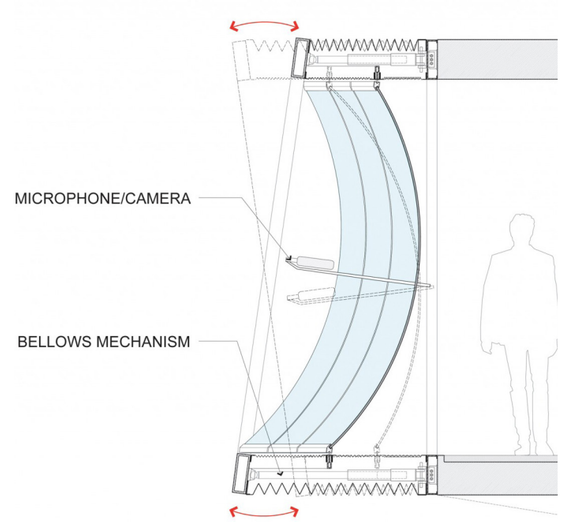
(Left) Diagram of Mix House by Joel Sanders Architects (2006) displaying typology and locations of audio and vision augmentation devices **[Fig. 3.30]**

(Centre) Audio visual transparency **[Fig. 3.31]**



[Fig. 3.32] **(Above) Plan of Mix House illustrating spatial relationship generated by sensory augmentation**

[Fig. 3.33] **(Below) Detail section of pivoting picture window located in living room**



environments is broken such that the merging of programmatic elements livens the spatial quality of the dwelling, generating a new form of living, working, and sleeping.[48]

WEARABLE ARCHITECTURE AS POLITICAL STATEMENT

Lucy Orta's deployable and wearable works are born out of a critique towards issues of urban alienation and homelessness, issues prevalent in urban centres where changes are seen in structures of family.[49] Her works are statements about the need for new forms of inhabitation. *Refuge Wear* [1998 - 2005] is geared towards raising awareness of rampant homelessness in society, and so she utilizes scales of clothing, an extension of the skin, as varying layers of heat-controlled mechanisms, where housing and clothing become twins.[50] [Fig. 3.34] [Fig. 3.35] Orta creates portable architectures such as survival suits and refuge wear. These are seen as parkas, anoraks, ponchos, tents, sleeping bags, and furniture. These then become layers of inhabitation, such that underwear is considered a crucial component in her work to house the homeless. This extends into layers of the overcoat, the sleeping bag, and the tent as the outermost layer. Each unit of clothing consists of modular textiles, and flexible architectural components that can be transformed into individual or collective survival shelters. [Fig. 3.37] These are all made of durable weaves, synthetic fibres

(Left) Refuge Wear - Mobile Cocoon with Detachable Baby Carrier (1994), Lucy Orta [Fig. 3.34]

(Centre) Refuge Wear (video) (1998), Lucy Orta [Fig. 3.35]

[Fig. 3.36] (Above) Nexus Intervention with Architecture Students from the Technischen Universitat Berlin (2011), Lucy Orta

[Fig. 3.37] (Below) 70 X 7 The Meal, Act X, NAPA (M.I.U. V) (2002), Lucy Orta

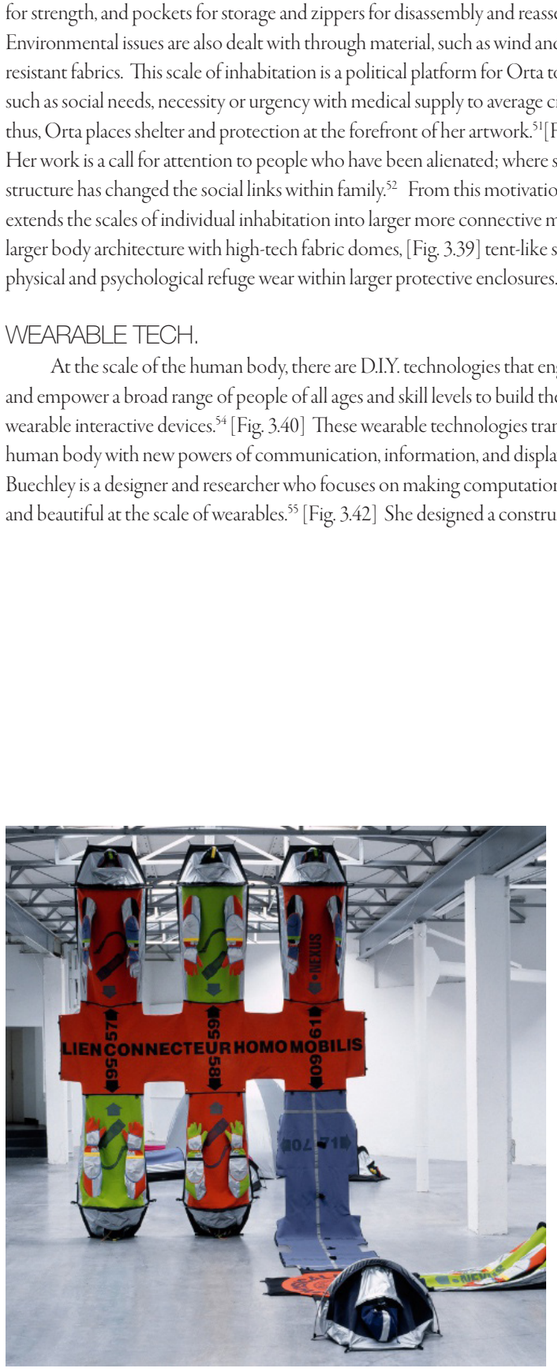
for strength, and pockets for storage and zippers for disassembly and reassembly. Environmental issues are also dealt with through material, such as wind and water-resistant fabrics. This scale of inhabitation is a political platform for Orta to address, such as social needs, necessity or urgency with medical supply to average citizens; thus, Orta places shelter and protection at the forefront of her artwork.[51][Fig. 3.38] Her work is a call for attention to people who have been alienated; where societal structure has changed the social links within family.[52] From this motivation, Orta extends the scales of individual inhabitation into larger more connective modes of larger body architecture with high-tech fabric domes, [Fig. 3.39] tent-like structures, physical and psychological refuge wear within larger protective enclosures.[53]

WEARABLE TECH.

At the scale of the human body, there are D.I.Y. technologies that engage and empower a broad range of people of all ages and skill levels to build their own wearable interactive devices.[54] [Fig. 3.40] These wearable technologies transform the human body with new powers of communication, information, and display. Leah Buechley is a designer and researcher who focuses on making computation soft and beautiful at the scale of wearables.[55] [Fig. 3.42] She designed a construction kit

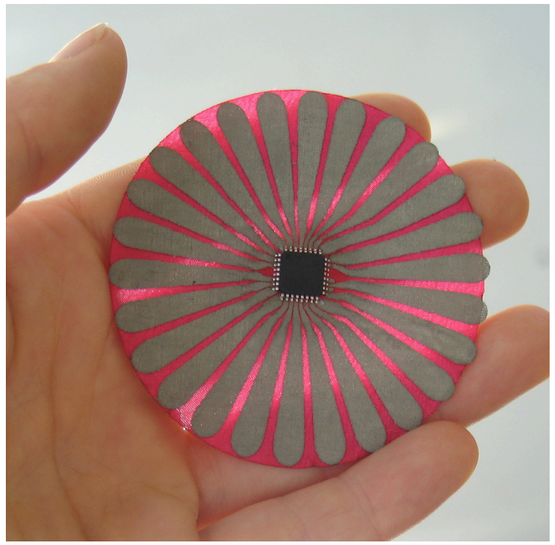
(Left) Connector Mobile Village II (2001), Lucy Orta **[Fig. 3.38]**

(Centre) Body Architecture - Foyer D (2002), Lucy Orta **[Fig. 3.39]**



[Fig. 3.40] **(Above) Bracelets (2005 - ongoing), Leah Buechley**

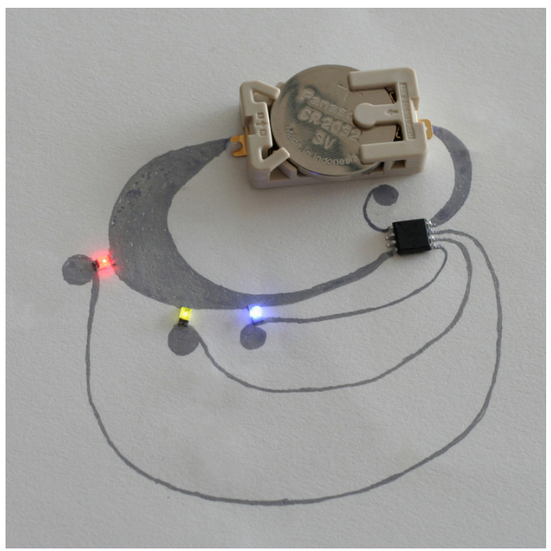
[Fig. 3.41] **(Below) ProjectLilyPad Arduino (a construction kit for electronic textiles) (2007), Leah Buechley**



that enables people to build their own software and interactive wearables. Her kits include micro-controllers, sensors, actuators, and pieces sewn with conductive thread that allows for both electrical and physical connections. With Arduino software as the main communicative hub for each actuator, they form from the bottom-up an e-textile that is lightweight and attachable to the human body.[56] [Fig. 3.41] Fabric-printed circuit boards in the shape of flowers or lily pads give visual and structural arrangements to circuit boards. [Fig. 3.43][Fig. 3.41] Accessories are also able to act as nodes, main communicative platforms, or control points to other secondary actuators. Furthermore, Adafruit Industries [Fig. 3.44] are an open source hardware shop with a community that aids the everyday layman with learning the craft of electronics that can be worn. [Fig. 3.45] Much of the focus of these electronics and circuit boards can be implemented on cloth with conductive thread, L.E.D.s, beads and electronics.[57]

(Left) Painting, Leah Beuchley [Fig. 3.42]

(Centre) Living Wall: programmable wallpaper for interactive spaces (2010), Leah Beuchley [Fig. 3.43]



[Fig. 3.44] (Above) Limor "ladyada" Fried at Adafruit Industries

[Fig. 3.45] (Below) City Bike Helmet (2013), Adafruit Industries

ACTIVE OUTDOOR GEAR

Today, backpacking, hiking, or, alternatively bivouacking, are synonymous with travelling lightweight, so that one can simply exist with the great outdoors.[58,59] Backpackers, mountaineers and hikers, like the military of ancient Rome, have similar objectives, such that they need to sustain long periods of outdoor living. It is important to note that active outdoor gear draws roots in the standard issue military equipment of ancient Rome. To deal with harsh conditions of long travel, a typical Roman soldier had equipment that was lightweight so that the soldier was comfortable.[60] His equipment reflected concerns for not only weight but mobility, adaptability, functionality, and durability.[61] A prime example was a boot called a caligae,[62,63] [Fig. 3.46] made of a single piece of leather laced all the way up the foot to construct its upper. This form of construction created a unique sole pattern that distributed the wearer's weight allowing him to carry, 10 lbs of cotton and hemp cordage, wooden supports with ferrules of solid iron, plus stakes to set up an encampment around a campfire.[64] In contrast to the active outdoor gear of today, equipment then was not light; however, one still had to cover as much ground in a day's march, as possible. The bivvy sac, short-form for undertaking the activity of utilizing a bivouac, allowed military patrols or watches to set up a bare minimal temporary encampment with few facilities.[65] A military patrol would usually scout the area so that they could detect the presence of the enemy, communicate a message to another party, or be as close as possible with the enemy; and so travelling discreetly was a must.[66] A bivouac sac consisted of a 6ft-by-6ft tarp that wrapped the body and protected it against general climate conditions such as rain.[67] [Fig. 3.47]

[Fig. 3.46] **(Left) Miltary Foortwear (Antoninus Pius) and Hunters - Vitican Museums**

[Fig. 3.47] **(Right) Outdoor Research Advanced Bivy Sack, MEC**

ADVANCED WEARABLE MATERIALS

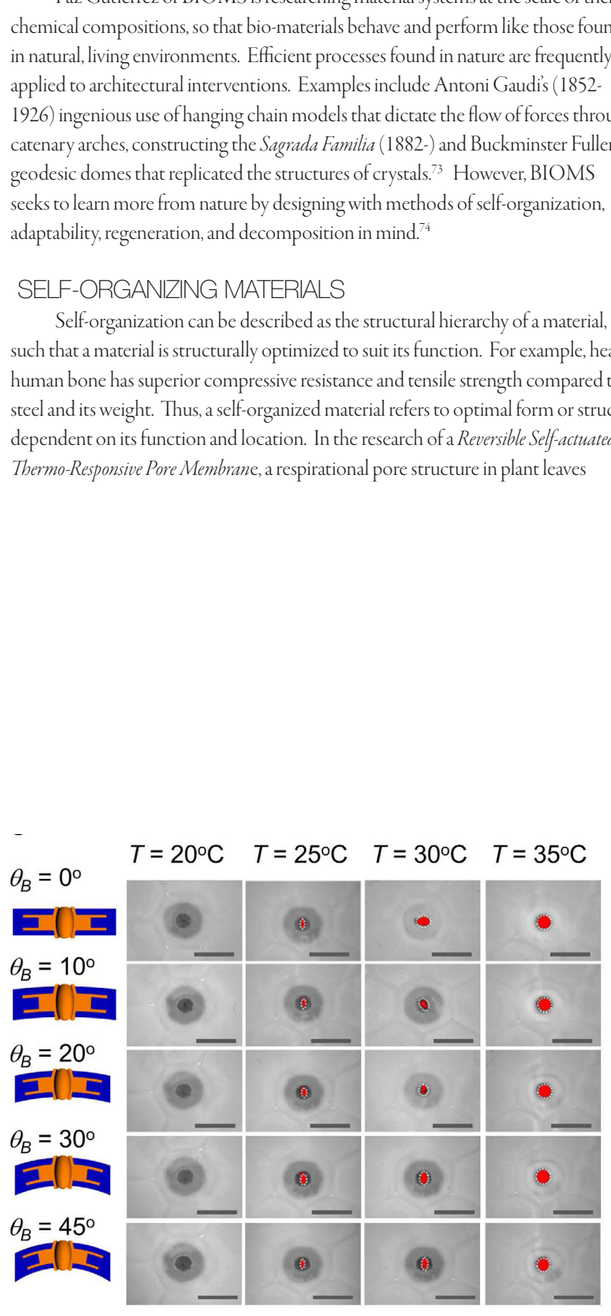
Material advances in active outdoor gear include lightweight, high-tensile strength synthetic fibres such as ultra-high-molecular-weight polyethylene (UHMwPE) that comprise tent shells, clothing and ropes.[68] Storage components such as backpacks are comprised of composite carbon fibre frames with laminated fabrics and synthetic fibres to hold loads and resist abrasion and environmental influences like solar deterioration.[69,70] Other structural components include walking poles made of composite carbon fibres. There are also energy-harvesting tools, materials[71], and techniques that allow the users to gather energy from the sun and surroundings so that quotidian tasks can be completed.[72] [Refer to design section Fig. 5.32 & Fig. 5.33]

BIOMS (BIO INPUT ONTO MATERIAL SYSTEMS)

Paz Gutierrez of BIOMS is researching material systems at the scale of their chemical compositions, so that bio-materials behave and perform like those found in natural, living environments. Efficient processes found in nature are frequently applied to architectural interventions. Examples include Antoni Gaudi's (1852-1926) ingenious use of hanging chain models that dictate the flow of forces through catenary arches, constructing the *Sagrada Familia* (1882-) and Buckminster Fuller's geodesic domes that replicated the structures of crystals.[73] However, BIOMS seeks to learn more from nature by designing with methods of self-organization, adaptability, regeneration, and decomposition in mind.[74]

SELF-ORGANIZING MATERIALS

Self-organization can be described as the structural hierarchy of a material, such that a material is structurally optimized to suit its function. For example, healthy human bone has superior compressive resistance and tensile strength compared to steel and its weight. Thus, a self-organized material refers to optimal form or structure dependent on its function and location. In the research of a *Reversible Self-actuated Thermo-Responsive Pore Membran*e, a respirational pore structure in plant leaves

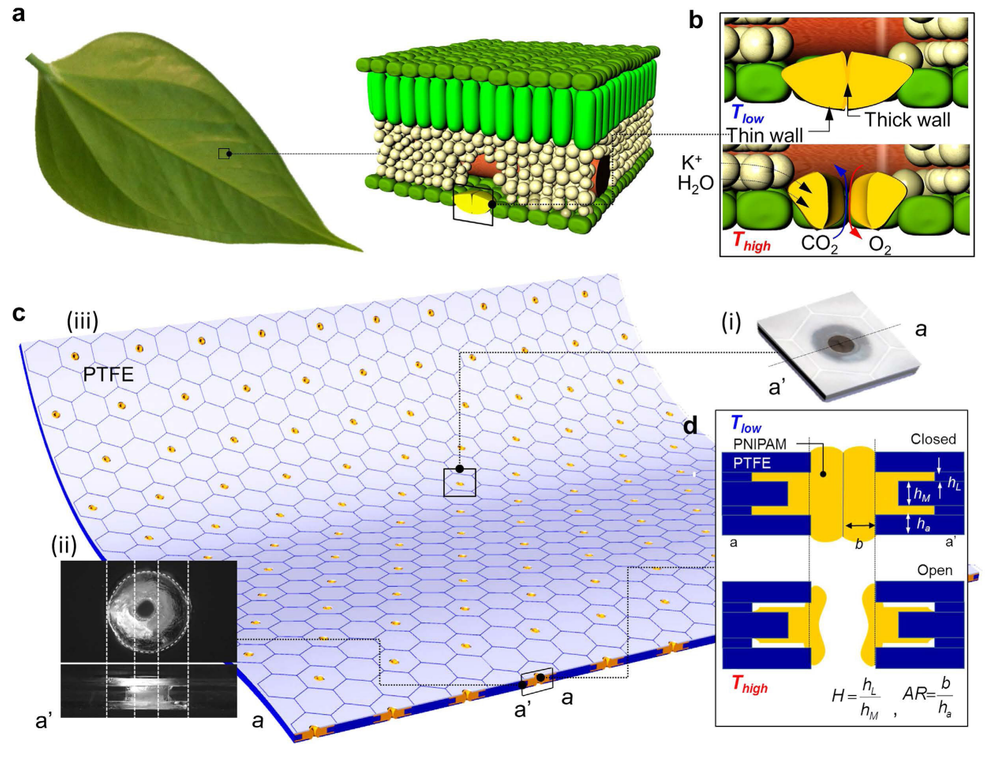


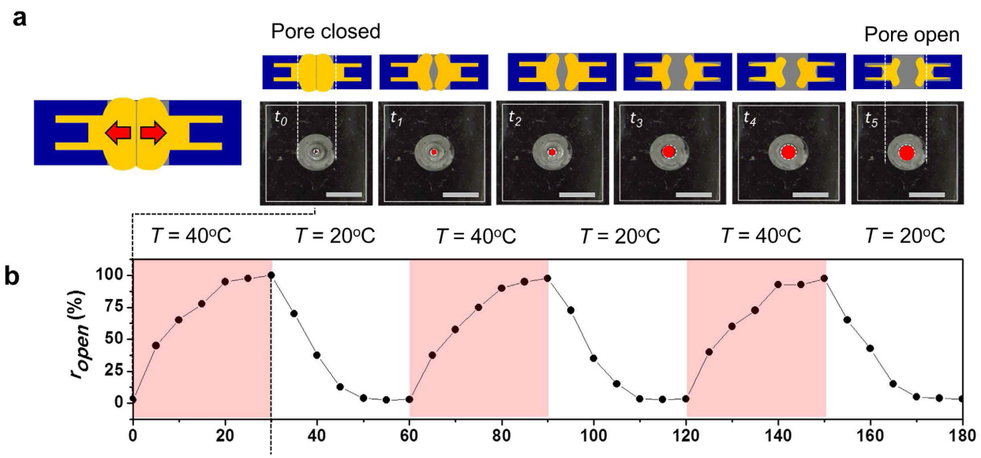
(Left) Pore images bending from 0^0 to 45^0 at different termperatures, Park Y., Gutierrez M.P., Lee L.P.

[Fig. 3.48]

(Centre) Inspirations from respirational pore structure of a plant leave to thermo-responsive pore opening and closing structure, Park Y., Gutierrez M.P., Lee L.P.

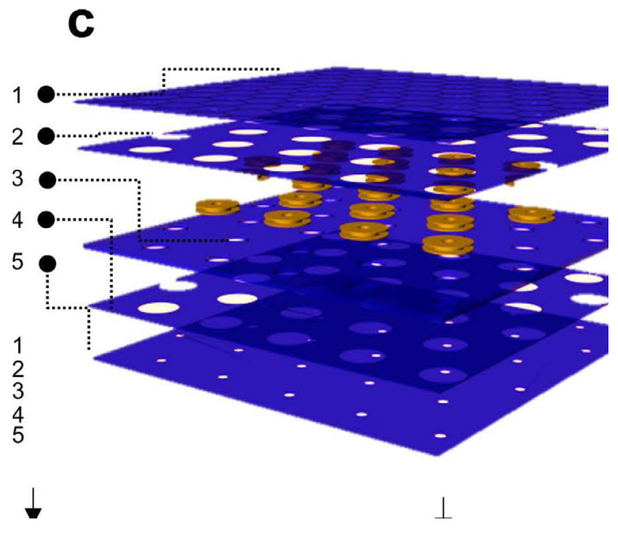
[Fig. 3.49]





[Fig. 3.50] (Above) Cycle of pore opening and closing dependent on environmental temperature at 20^0C and 40^0C, Park Y., Gutierrez M.P., Lee L.P.

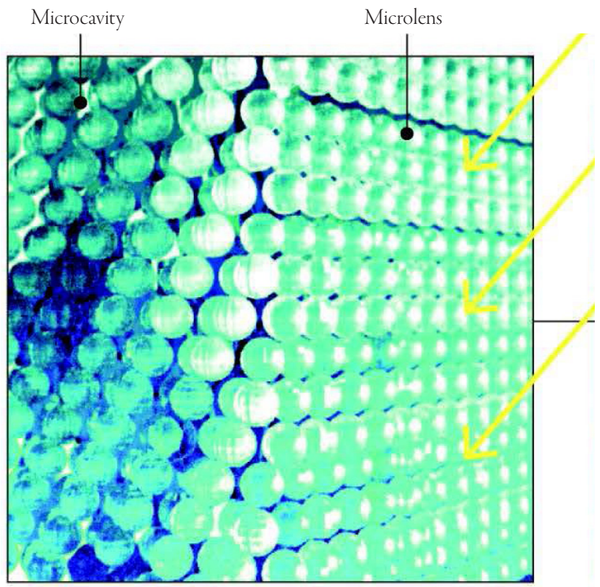
[Fig. 3.51] (Below) Large area film assembly with multidimensional pore structure, Park Y., Gutierrez M.P., Lee L.P.



confirmed the researcher's hypothesis that pore openings with varying dimensions influence potential ventilation rates of a designed membrane.[75] Pores of the designed membrane open at 40°C in twenty minutes and close at 20°C.[76] Five layers of polytetrafluoroethylene (PTFE) [Fig. 3.51] with different sized pore diameters along with cross-sectional dimensional variances are structured in a way that influence its responsive behavior to environmental temperature change while maintaining structural performance.[77]

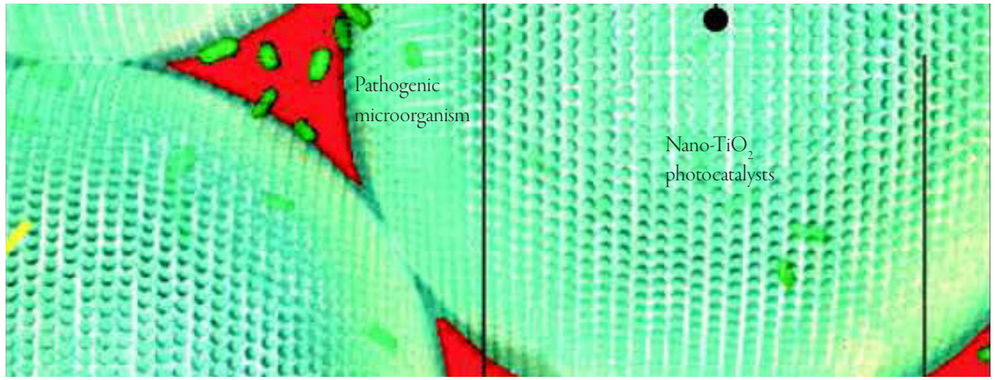
ADAPTABILITY IN BUILDING MATERIALS

Adaptability in material systems encompass the multi-functionality of a designed material. *Solar Optics-Based Active Panel (SOAP) for Solar Energy Storage and Disinfection of Greywater* enables both solar energy storage and photothermal disinfection of greywater simultaneously.[78] [Fig. 3.53] Mirrors and lenses heat water causing the complete inactivation of E. coli in greywater, the process is aided by solar UV radiation. [Fig. 3.52] [Fig. 3.54] Nano particles in a liquid absorb solar radiation and are stored and later converted with a thermoelectric convertor or used for radiant floor heating in the building.[79] Optical concentration devices are used to ensure high solar radiative flux with low thermal losses, while its disinfection rate



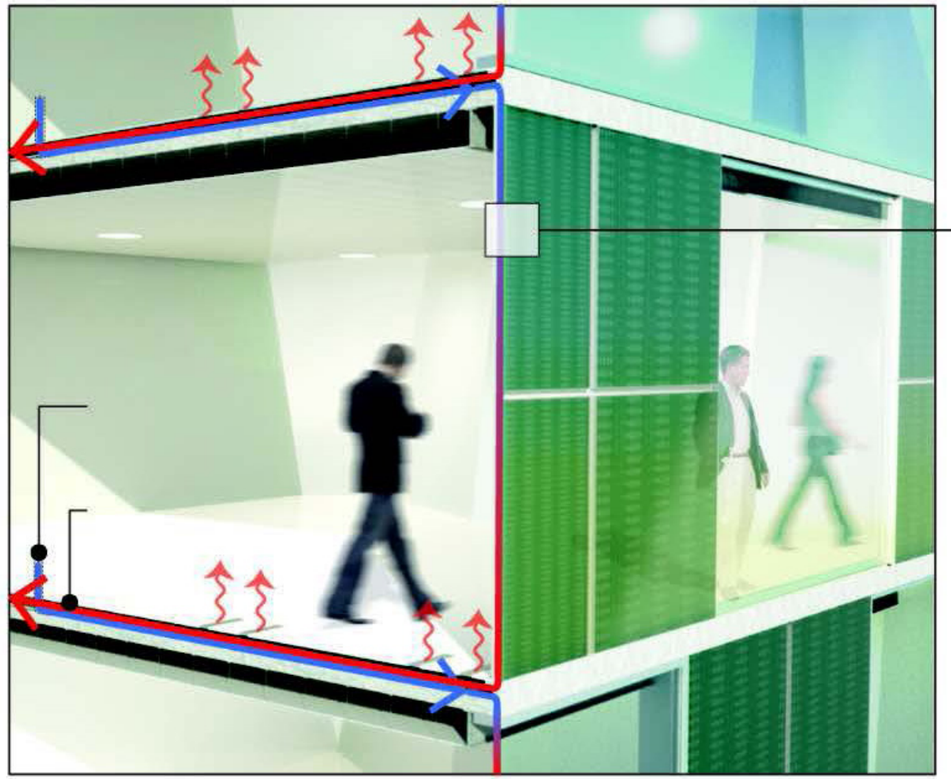
(Left) A photocatalytic optofluidic network with multiple layer of integrated photocatalytic reactors, (2016), Gutierrez M.P., Lee L.P. **[Fig. 3.52]**

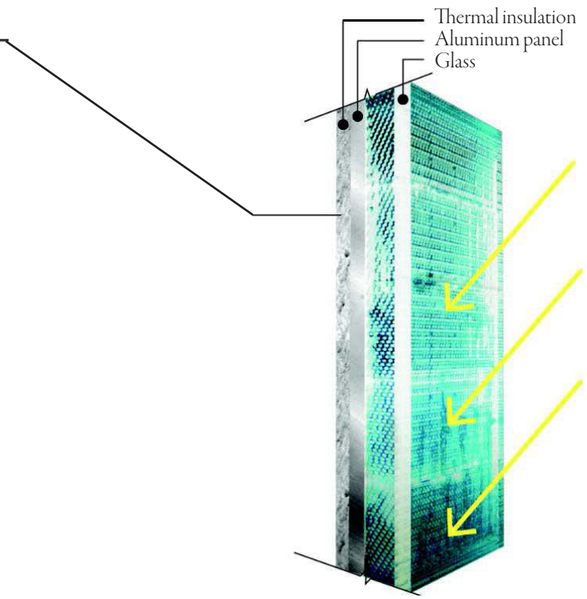
(Centre) A schematic axonometric drawing of SOAP decentralization system: graywater collection, solar-activated disinfection (facade) and recirculation (radiant floor heating) (2016), Gutierrez M.P., Lee L.P. **[Fig. 3.53]**



[Fig. 3.54] (Above) Pathogenic microorganisms disinfected via photocatalytic TiO_2 nanoparticles (2016) Gutierrez M.P., Lee L.P.

[Fig. 3.55] (Below) A single SOAP panel (2016), Gutierrez M.P., Lee L.P.





is in proportion to its lens diameter.[80] Normally, solar optic systems are focused on the generation of energy, separate from regeneration of water and processing of waste. The *SOAP* wall system allows for both processes to occur, resulting in threefold management of water, energy, and waste.[81]

REGENERATION IN BUILDING MATERIALS

Regeneration in biology usually describes an ability of a substance to repair its own tissues or fibres. However, in material systems, regeneration can be described as the life span, durability, and cost of material because these factors include the potential of recyclability, resistance to degradation, and other time-based variables that influence the life of the material.[82] BIOMS research in the *Effective Reflectivity and Heat Generation in Sucrose and PMMA Mixtures*[83] reveals the high performance characteristic of poly-methyl-methacrylate (PMMA) in terms of weathering resistance and high, upper-stress limits that render it suitable for façade applications, compared to other thermoplastics. [Fig. 3.70] PMMA as a building material has desirable optical and mechanical properties, with easy forming and surfacing characteristics. The material is simple to produce and can be used to replace broken or heavier, less performative materials on the market, which yields advantages in weight and cost of PMMA.

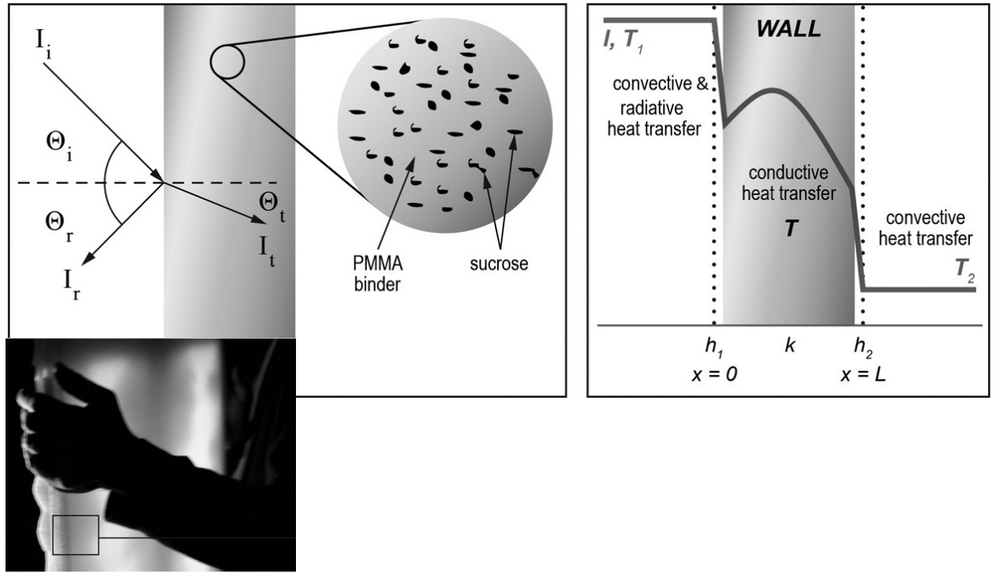
RECYCLABILITY AND BIODEGRADABILITY IN BUILDING MATERIALS

While recyclability of PMMA presents crucial challenges, BIOMS research in PMMA and agricultural waste mixtures such as sucrose allow for advantages in optics and lower embodied energy, which can outperform glass.[84] Sucrose and PMMA mixtures reduce material costs by 25% that of traditional glass, have 24% the total embodied energy of glass and 40% of PMMA panels by itself.[85] This material has potential to be applied to building envelopes where energy losses are concentrated. An agro-based PMMA and sucrose mixture can provide thermal insulation and daylight transmission control to building enclosures.[86] [Fig. 3.71] Furthermore, these material mixtures decrease heat gains by absorption as a function of sucrose and PMMA properties.[87] Traditional glass films or active dyes are used to control thermal and optical performance. However, agricultural waste mixtures such as bamboo particles or sucrose with PMMA allow for the advancement of biopolymers to achieve environmentally sensitive solutions in existing building materials.[88v]

(Below) Properties of thermoplastics used in exterior buildings applications, Gutierrez M.P., Lee L.P. **[Fig. 3.56]**

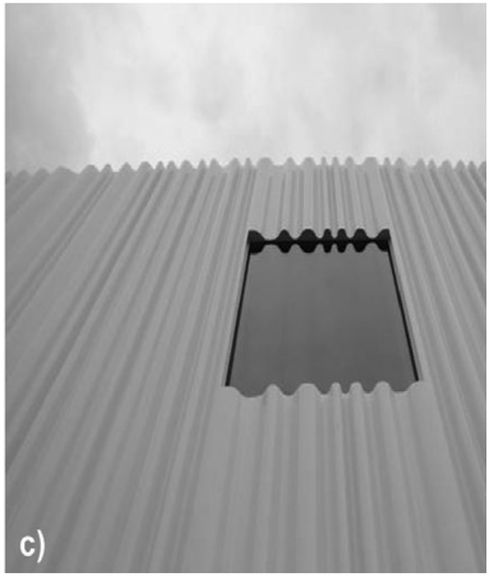
	DENSITY [g/cm³]	SERVICE TEMP. LONG / SHORT [°C]	TENSILE STRENGTH [N/mm²]	ELASTIC MODULUS [N/mm²]	COEFF. OF LINEAR THERMAL EXPANSION [10⁻⁶/K]	THERMAL CONDUCTIVITY [W/mK]	RESISTANCE TO CHEMICAL ATTACK FROM: acids	alkalis	weather
PE LD	0.92	60-75/80-90	8-23	200-500	230-250	0.32-0.40	●●●●	●●●●	○
PE HD	0.95	75-90/90-120	18-35	700-1400	120-200	0.38-0.51	●●●●	●●●●	○
PMMA	1.19	65-90/85-100	50-77	1600-3600	70-90	0.18	○○	●●●●	●●●●
PC	1.20	135/160	56-67	2100-2400	60-70	0.21	○○		○○
PET	1.37	100/200	47	3100	40-60	0.24	○○○	○○○	○○
PTFE	2.17	250/300	25-36	410	120-250	0.25	●●●●	●●●●	●●●●
ETFE	1.75	150/220	35-54	1100	40	0.23	●●●●	●●●●	●●●●

[●●●●] excellent, [●●●] good, [●●] some, [●] little, [ ] none



(Facing page top) PMMA sucrose mixture prototype, light diagram and heat transfer diagram, Gutierrez M.P., Lee L.P. **[Fig. 3.57]**

(Facing page bottom) Corrugated PMMA panels used on exterior facades of buildings, Gutierrez M.P., Lee L.P. **[Fig. 3.58]**



TRAJECTORY

The research mentioned above is a cluster of material precedents that occur beyond the scale of classical architecture, but at another scale that privilege integration of materials at the scale of wearables, creating immersive environments.[89] These wearable architectures act as interfaces between inhabitants and surroundings, creating personal expansive spaces, co-generated environments, and dynamic spaces with cycling energies. These interfaces explain many different contextual influences afforded by wearable architecture, such that the scales of influences, from prosthetic enhancements and modifications to the human psyche and micro- and nano-structures with light weight material surfaces, can allow for new forms of influence over the human body so that one can engage with the world more than ever before. Designers and architects are now armed with a great number of material tools and techniques to approach sustainable living.

END NOTES

1. Cybernetic systems of data exhibit regulated flows of information for communication. This can also be seen as a form-reflexive dialogue between humans and data. Thus, a cybernetic body part implies an interdependence between human body and machine such that a cyborg, can not exist by itself, but is in constant communication between virtual reality and reality. The augmented body part would be in constant dialogue with the human body to actively steer itself, in conjunction with the body, towards a shared goal. It would also involve a mutual and symbiotic interdependence between human body and technology.; Beer, Stafford. Designing Freedom. Concord, Ont.: Anansi, 1993.
2. Clynes, E. Manfred and S. Nathan Kline. "Cyborgs and Space." Astronautics, no. September (1960).
3. Ibid.
4. Haraway, Donna Jeanne. Simians, Cyborgs, and Women : The Reinvention of Nature. New York: New York : Routledge, 1991.
5. Ibid.
6. Braidotti speaks about blurred machines, organisms, objects and nature.; Braidotti, Rosi, author. The Posthuman. Cambridge, UK: Polity Press, 2013.
7. Haraway, Donna Jeanne. Simians, Cyborgs, and Women : The Reinvention of Nature. New York: New York : Routledge, 1991.
8. Ibid.
9. Mitchell, William J. 1995. City of Bits Space, Place, and the Infobahn, edited by Inc NetLibrary. Cambridge, Mass.: MIT Press.
10. Cyborgs exercise new personal spatial sentiments which require new kinds of shelter. According to Donna Haraway, the cyborg is the becoming of a free and worldly being. Her writings on the Chthulucene (chthon meaning "earth" in Greek and associated with things that dwell in or under the earth) suggests that the Chthulucene will be the age in which humans recall chtonic powers to collect waste and exterminism of the Anthropocene and Capitalocene. The post-human was to be more of a process of composting, such that the idea of a world could be habitable. These enhancements to the human species render its users cyborgs.; Haraway, Donna Jeanne, author. Staying with the Trouble: Making Kin in the Chthulucene. Durham: Duke University Press, 2016.
11. Ibid.
12. See Scaffolds; Beesley, Philip. "Living Architecture Systems Group White Papers." In, edited by Roushan, Ala. Final ed., p.363-3. Waterloo, Ontario: Riverside Architectural Press, 2016.
13. The first application of the term cyborg was during the 1960s space race.; Clynes, E. Manfred and S. Nathan Kline. "Cyborgs and Space." Astronautics, no. September (1960).
14. Donna Haraway states that nature is constructed, not discovered, truth is made and not found.; Haraway, Donna Jeanne. Simians, Cyborgs, and Women : The Reinvention of Nature. New York: New York : Routledge, 1991.
15. See writings on recombinant architecture, urban realms as soft cities and electronic agoras.; Mitchell, William J. 1995. City of Bits Space, Place, and the Infobahn, edited by Inc NetLibrary. Cambridge, Mass.: MIT Press.
16. Haraway, Donna Jeanne, author. Staying with the Trouble: Making Kin in the Chthulucene. Durham: Duke University Press, 2016.
17. Variables like heat, air, smell, sound (sensible by human bodily senses) are associations that can create architectural spaces. The nostalgia of childhood, the protective nostalgia of the mother, and melancholic nostalgia are connected to architectural space. Vidler writes about new ways of defining architectural spaces, known as cyborg homes.; Vidler, Anthony. The Architectural Uncanny : Essays in the Modern Unhomely. Cambridge, Mass.: MIT Press, 1992.
18. Michelle Addington speaks about the forgotten and neglected variables of defining spaces such as body heat and other additional layers that allow us to feel. ; Addington, Michelle. "Contingent Behaviours." Architectural Design 79, no. 3 (2009): p.12-17.
19. Luis Fernández-Galiano speaks about energy and its ability to redefine architectural space-making with energies that are tangible and crucial to architecture.; See Fernández-Galiano, Luis. Fire and Memory on Architecture and Energy. Cambridge, Mass.; London: MIT Press, 2000.
20. According to Sean Lally, there is potential for people to interface their body with their surroundings so that architecture can move beyond visible spatial boundaries and borders between human and nature.; Lally, Sean. "Sensorial Envelopes." In The Air from Other Planets: A Bried History of Architecture to Come. Zurich: Lars Muller Publishers.
21. All biological organisms act autonomously. The autonomous is unseen, such that biology has an innate ability to do everything, while doing nothing. Biology just works and, at times, it can be aided by or be dependent upon a mechanical or electronic device or biological addition. Thus, a cyborg is simply a cluster of autonomous networks.
22. Machines and human relationships is a critical discourse examined by Canguilhem. According to Canuilhem, the machine was a guiding device and/or legislator. Furthermore, he states that the machine, in the hand of God, was capable of greater action then in the hand of humans.; Canguilhem, Georges. "Machine and Organism." In Incorporations, edited by Crary, Jonathan and

Sanford Kwinter, p.44-69. New York, NY: New York, NY : ZONE, 1992.
23. Manifestoes such as Le Corbusier's Towards a New Architecture: Guiding Principles (1920), Guiding Principles of Town Planning (1925), Five Points Towards a New Architecture (1926) and R.Buckminster Fuller's Universal Architecture (1932) refer to the notion of machines in architecture. See Conrads, Ulrich and William Dendy. Programs and Manifestoes on 20th Century Architecture. 1st pbk. ed. ed. Cambridge, Mass.: Cambridge, Mass. : MIT Press, 1975.
24. Ibid. p. 59, 89, 99, 128
25. Ibid. p. 59, 89, 99, 128
26. See Machine as Organism; Canguilhem, Georges. "Machine and Organism." In Incorporations, edited by Crary, Jonathan and Sanford Kwinter, p.44-69. New York, NY: New York, NY : ZONE, 1992.
27. Conrads, Ulrich and William Dendy. Programs and Manifestoes on 20th Century Architecture. 1st pbk. ed. ed. Cambridge, Mass.: Cambridge, Mass. : MIT Press, 1975, p. 99
28. Camouflage is a notion seen as a dissolving and solidifying boundary defined by many psycho-social realms of the human body.; Leach, Neil. Camouflage. Cambridge, Mass.: MIT Press, 2006.
29. See Constructivism.; Elderfield, John. Modern Painting and Sculpture: 1880 to the Present at the Museum of Modern Art. New York: Museum of Modern Art, 2004. Print.
30. Cruz refers to changes of bodily spatial perception over the course of the twenty-first and twentieth century.; Cruz, Marcos. The Inhabitable Flesh of Architecture. Design Research in Architecture., edited by Fraser, Murray, Jonathan Hill and Jane Rendell Ashgate Publishing Limited, 2013, p.17
31. See Archigram.; Gleiniger, Andrea and Georg Vrachliotis. Complexity : Design Strategy and World View. Basel ; Boston: Birkhäuser, 2008.
32. Sadler, Simon. Archigram Architecture without Architecture /, edited by Simon Sadler. Cambridge, Mass. : MIT Press, c2005, 2005.
33. "The Archigram Archival Project." Research Centre for Experimental Practice at the University of Westminste2017. http://archigram.westminster.ac.uk/.
34. "Walking City." Research Centre for Experimental Practice at the University of Westminster2017. http://archigram.westminster.ac.uk/project.php?id=60.
35. Awan, Nishat. "Haus-Rucker-Co." University of Sheffield2017. http://www.spatialagency.net/database/how/networking/haus-rucker-co.
36. "The Archigram Archival Project." Research Centre for Experimental Practice at the University of Westminste2017. http://archigram.westminster.ac.uk/.
37. Banham, Reyner. The Architecture of the Well-Tempered Environment, edited by Dendy, William. London : Chicago; Chicago; London, Architectural Press (1969): London : Architectural Press ; Chicago : University of Chicago Press, 1969.
38. Banham, Reyner. The Architecture of the Well-Tempered Environment, edited by Dendy, William. London : Chicago; Chicago; London, Architectural Press (1969): London : Architectural Press ; Chicago : University of Chicago Press, 1969.

39. Gutierrez, Paz. "Material Bio-Intelligibility." (2008).
40. Addington, D. Michelle, Amale Andraos, A. Barber, Bayer Eben Daniel, Blaine Brownell, Carlisle Stephanie, Andrew Dent, et al. Embodied Energy and Design, edited by Benjamin, David 2017.
41. BIOMS (Gutierrez, Paz et al.) presents research that shapes the surrounding environment of buildings at a micro and nano scale.
42. The Living (Benjamin, David et al.) presents research that shapes the environment of buildings by addressing material networks of buildings and viewing it as a tangible embodied energy felt by inhabitants and designers.
43. Scott, Craig and Lisa Iwamoto. "Jellyfish House." 2016. https://iwamotoscott.com/projects/jelly-fish-house.
44. Electrochromic fenestration functions as a disruptive patterning system that camouflages the building's interior organization. When an electrical supply is switched on, liquid crystal molecules align and incident light passes through for transparent glass. When power is switched off, liquid crystal molecules return to a scattered alignment, blocking light from passes through allowing for opaque glass.
45. Faulders, Thom. "Chromogenic Dwelling." 2016. http://faulders-studio.com/CHROMOGENIC-DWELLING.
46. Sanders, Joel. "Immersive Environments: Media, Architecture and Landscape."University of Waterloo, Arriscraft Lecture, October 30, 2014, 2014.
47. Ibid.
48. Ibid.
49. Paul Virilio (1996), Refuge Wear, Paris: Editions Jean Michel Place.
50. Quinn, Bradley. "Lucy Orta." In Techno Fashion, p.19-26. Oxford UK; NewYork, NY, USA: Berg, 2002.
51. Ibid.
52. Paul Virilio (1996), Refuge Wear, Paris: Editions Jean Michel Place.
53. Ibid., p. 22.
54. Seymour, Sabine. Fashionable Technology the Intersection of Design, Fashion, Science, and Technology. Wien ; New York; Wien ; New York, NY: Springer, 2008.
55. See Leah Buechley, p. 120-122.; Ibid.
56. See LilyPad Arduino, p. 192- 193.; San Martin, Macarena. Future Fashion : Innovative Materials and Technology = El Futuro De La Moda, Tecnologia y Nuevos Materiales. Palermo: Promopress, 2010.
57. Zax, David. "The TV on Your Shirt." (2012): 2018.
58. Great compendium of layers, materials and items for travelling outdoors.; Skurka, Andrew. The Ultimate Hiker's Gear Guide, Second Edition: Tools and Techniques to Hit the Trail. Washington, DC: National Geographic Partners, 2017.
59. Canterbury, David. Advanced Bushcraft: An Expert Field Guife to the Art of Wilderness Survival. Avon, MA, USA: Adams Media, 2015.
60. Croom, Alexandra. Roman Clothing and Fashion. 1st pbk. ed. ed. Stroud England] ; Charleston, SC: Tempus, 2002.
61. See Material Checklist, p. 30-83.; Skurka, Andrew. The Ultimate Hiker's Gear

Guide, Second Edition: Tools and Techniques to Hit the Trail. Washington, DC: National Geographic Partners, 2017.
62. Griffith, Sarah. "Step Back in Time: Roman Footprints Discovered in Israel Reveal Details of 1st Century Soldiers' Hobnail Boots." Daily Mail,2015.
63. Turnbull, Ronald. "Bivvy History." In The Book of the Bivy, p. 19-28. Singapore: KHL Printing, 2007.
64. Ibid.
65. Ibid.
66. Ibid.
67. Ibid.
68. UHMwPE comes in four form factors: fibre, tape, fabric and unidirectional sheets. Its extreme strength and low weight allow it to be 15 times stronger than steel in strength to weight ratio, have low elongation breaks, high resistance to abrasion, moisture, UV, radiation and chemicals, to float on water, be highly flexible and have high energy absorption.; "Dyneema." 2017. http://www.dsm.com/products/dyneema/en_GB/home.html.
69. See Tools & Techniques.; Skurka, Andrew. The Ultimate Hiker's Gear Guide, Second Edition: Tools and Techniques to Hit the Trail. Washington, DC: National Geographic Partners, 2017.
70. MEC. "Camping and Hiking Clothing, Jackets, Tops, Pants and Shorts." 2017. https://www.mec.ca/en/gender/men%27s/products/clothing/jackets/c/1018.
71. See Figure 4-1 in Appendix, A Sampling of different Type 1 and Type 2 smart materials in relation to input and output stimuli.; Addington, D. Michelle and Daniel L. Schodek 1941. Smart Materials and New Technologies: For the Architecture and Design Professions. Architectural Press ed. Amsterdam ; Boston: Amsterdam, 2005.
72. Canterbury, David. Advanced Bushcraft: An Expert Field Guife to the Art of Wilderness Survival. Avon, MA, USA: Adams Media, 2015.
73. Sabin, Jenny E. and Peter Lloyd Jones. "Design Research in Practice: A New Model." In LabStudio : Design Research between Architecture and Biology, 31-43. New York, New York: Routledge, Taylor & Francis Group, 2018.
74. See introductory paragraph, Gutierrez states that all natural materials exhibit efficient processes of self-organization, adaptability, regeneration and decomposition.; Gutierrez, Paz. "Material Bio-Intelligibility." (2008).
75. Park, Younggeun, Paz Gutierrez, and Luke P. Lee. "Reversible Self-Actuated Thermo-Responsive Pore Membrane." (2016).
76. Ibid., p. 3
77. Ibid., p. 3
78. The research aims to approach net zero waste, energy, and water usage in buildings by making materials multi-functional. The article begins by stating that the problems that guide architectural research are depleting energy sources and water in the environment. 2.8 billion people in 48 countries will suffer from water scarcity in 2025 and regenerable greywater is being wasted; See Lee, W., J. Song, J. H. Son, Paz Gutierrez, Kang T., Kim D., and Lee L.P. "Solar Optics-Based Active Panel for Solar Energy Storage and Disinfection of Greywater." (2016).
79. Ibid.
80. Ibid.
81. Ibid.
82. The environmental impact of polymers leads to their re-evaluation of use in buildings. Polymers are commonly used as vapor barriers, protective coverings, paints, and insulation; Gutierrez, Paz and Tarek Zohdi. "Effective Reflectivity and Heat Generation in Sucrose and PMMA Mixtures." (2013).
83. Ibid.
84. PMMA and agro-based mixtures such as sucrose make it a biopolymer; biodegradable polymers; Ibid.
85. Ibid., p. 99
86. Ibid., p. 99
87. Ibid., p.99
88. Bamboo is a plant with the lowest embodied energy and carbon emission rate of all construction materials. Bamboo's carbon footprint is lower than hemp or flax, which are widely acknowledged as extremely low carbon footprint materials in construction. There are benefits to both bamboo particle and sucrose mixtures; however, in this study, optical properties of sucrose are desired.; Ibid., p. 98
89. Beesley, Philip and Sarah Bonnemaison. ""Where I Stand"." In Living Architecture Systems Group White Papers, edited by Roushan, Ala. Final ed., 64. Waterloo, Ontario: Riverside Architectural Press, 2016.

04
FILM PRECEDENTS

The following film precedents articulate a language about how one might live in the future. They inform changes to the human body, ways of living, as well as the human relationship with the drastically different ecologies of projected worlds. The following section is categorized into precedents regarding an expanded human physiology and future environments to inspire the final thesis design.

GHOST IN THE SHELL (2017)
DIRECTED BY RUPERT SANDERS
MIRA AND THE MONK HIVE

PREMISE

Ghost in the Shell (2017) is about a world inhabited by cyborgs and it reinterprets today's spaces for living, working, and sleeping. The film is set in the future of Japan, when humans no longer need their natural bodies to live. This is due to the advent of Cyberbrain technology,[1] [Fig.1] the main component of the human body to live in a digital and war-ridden world. Mira Killian is a cyborg, anti-cyber terrorist official whose home supports her desires to be more human than machine. On the other hand, Hideo Kuze is the vengeful antagonist who wants to get rid of his physical body and live inside a virtual network.

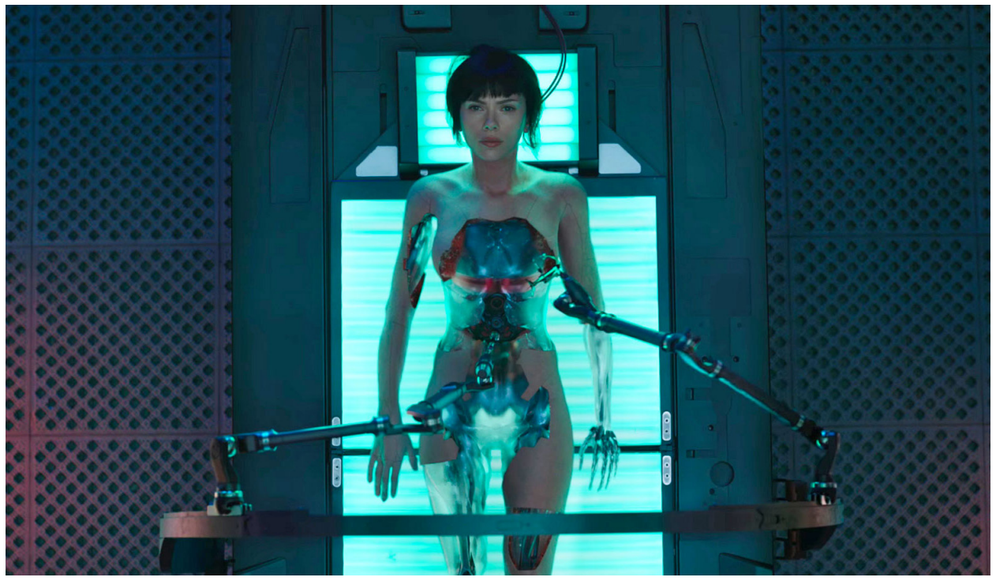
A SYNTHETIC BODY

The film presents a synthetic human body that can save humans from death and catastrophic accidents. Human bodies are subject to enhancement and repair from Hanka Robotics, a leading corporation specializing in augmentative technology. The human brain can co-exist within a mechanical body known as a shell. This type of technology reveals the theme of the film: the struggle in defining traits of humanity once the entire body is a machine. Mira Killian and Hideo Kuze both have synthetic bodies with their brains implanted within them. [Fig.2] They both have a port on their neck that enables them to virtually travel among the networks of data on the Internet. They occupy different shelters for survival because Mira Killian and Hideo Kuze have opposing views on what makes them human. The result can be seen in the spatial composition of their home. Mira Killian thinks that her actions define who she is rather than her memories, which explains the importance of the physical reality which she inhabits. In constrast, Hideo Kuze disregards his own body and the physical world, such that he prefers living in a virtual reality.

(Below) Mira Killian with Cyberbrain near her body, Ghost in the Shell 2.0 (1995) **[Fig. 4.1]**

(Facing page top) Killian's Shell, Ghost in the Shell (2017) **[Fig. 4.2]**

(Facing page bottom) Killian sitting in her living room recharging, Ghost in the Shell (2017) **[Fig. 4.3]**



KILLIAN

Killian's home has a space for living, working, and sleeping. Killian's home is barren, un-personalized, functional, pragmatic, without a space to cook and eat. The apartment also lacks a wash area and bathrooms. She has two spaces for relaxation. One is a pod that allows her to sit and day-dream, while the second is a lounge with semi-radial seating for company. A lounge indicates that Killian likes having people at her apartment, and that face-to-face interaction has meaning for her. Her apartment includes a work station, a table with tools for analyzing evidence from crime scenes. Adjacent to this room is storage for weapons and mechanical body parts to repair herself. Her bed is a charging station for her body with ambient lights stimulating her circadian rhythm while refuelling the battery cells in her mechanized body. A dominant characteristic of the apartment is pragmatism, expressed in spaces for work and the care of her mechanical body, but with less space to relax.

KUZE

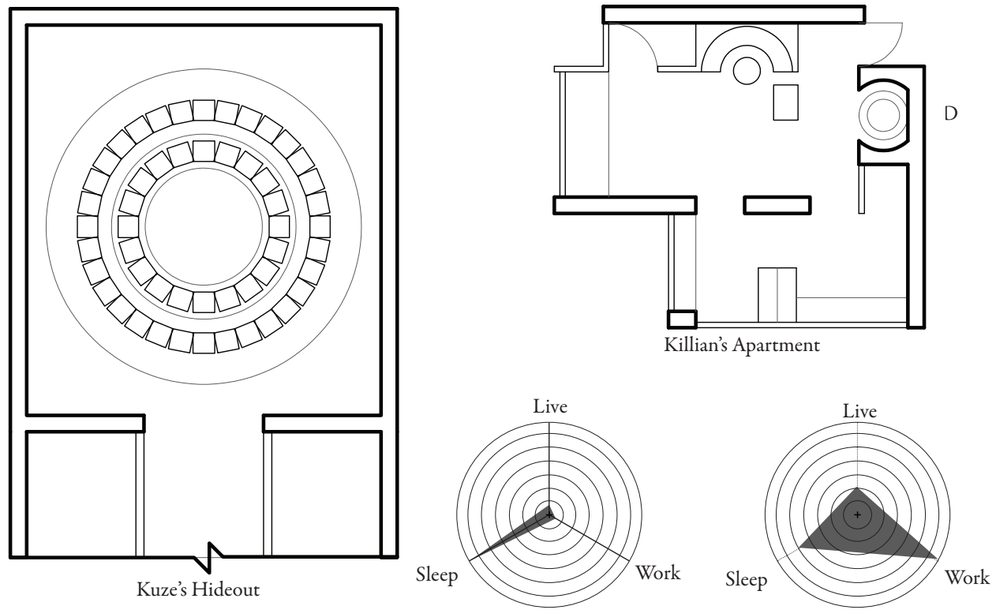
Another kind of spatial organization is portrayed through Kuze's cynical plans to create a society where individuals live within a mental neural network. By hard wiring people's minds together, the only purpose of the body is to sustain the brain. These people sit in an unlit room and are radially organized with each other, along with their heads connected with wires that converge and lead out into the physical world but only to connect to othersimilar spaces. Methods to fully sustain the body without leaving the mental neural network are still in progress, as there are people who have not survived due to this flaw. The mental neural network creates a collective consciousness of beings who can live freely and are not confined by their bodies. This space does not privilege relaxing but instead provides a space to day-dream forever.

CONCLUSION

The Cyberbrain, synthetic bodies of cyborgs as well as Mira Killian's and Kuze Hideo's homes in Ghost in the Shell produce architecture that is absent of space for living but are more inclined towards working and sleeping. The synthetic qualities of the cyborg diminish many of the traditional qualities of human life that people enjoy today, such as physical interaction with surroundings and face-to-face interaction with people and space to carry out hobbies. Instead, Killian and Hideo have no need for physical spaces to live or relax and wind down from a busy day. This is seen in their homes with objects and tools that facilitate the functions of the cyborg body. The film presents a dark trajectory of humans and their built environment in post- World War III Japan.

(Below) Stunt double wearing a Therm-optic suit prop. Suit in film can make the wearer invisible by bending light. **[Fig. 4.4]**

(Facing page) Spatial composition of Kuze's hideout vs Mira Killian's apartment **[Fig. 4.5]**



ALIEN (1979)
DIRECTED BY RIDLEY SCOTT
SPACE JOCKEYS AND THE DERLICT SPACE CRAFT

PREMISE

Alien (1979) presents the spatial composition of a space craft of an alien species in the future. The space craft is presented as a bio-mechanical system where humans are embedded in a system for functioning and living. Alien explores this notion with the artwork from H.R. Giger's Necronomicon to draw upon subjects and environments that are bio-mechanically fused together. The film constructs a future dystopic scenario when humans encounter a killer species called the Space Jockey, a terrifying interplanetary parasite. The relationship between the Space Jockey and humans influences the spatial organization and design of architectural sets in the film.

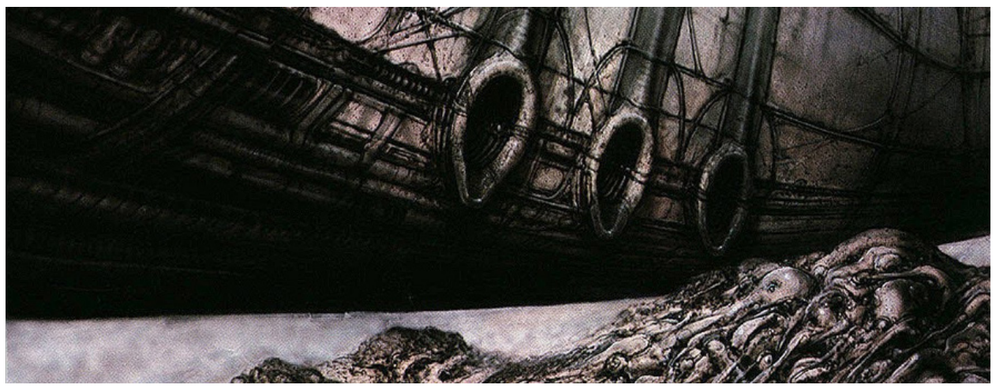
DERELICT SPACE CRAFT

The setting under investigation in Alien is the derelict space craft. It is a hybrid bio-mechanical life form/ space craft with a distinct pilot chamber, entrance, [Fig.6] floor, interior, texture, and cargo load. These elements highlight a living-building system. The artwork of H.R. Giger's Necronomicon suggests the space craft is not a static machine, but one that is actively participating in sustaining an alien life-form. The derelict space craft contains a pilot chamber with a living being fused to its chair, entrances that resemble orifices, floors that are not meant for walking on, skeletal interiors, and a breeding ground for eggs that hatch creatures that utilize human bodies as hosts to ensure their own survival.

THE PILOT

A deceased Space Jockey pilot is at the centre of a large domed interior of the space craft. His chair has a large targeting gun, perhaps for observing the universe or for

(Below) Derelict ship entrance, Work 275: Wreck, H.R. Giger (1978) [Fig. 4.6]



(Facing page) The space jockey chair, (1978), H.R. Giger [Fig. 4.7]

launching its cargo load of eggs at specific planetary targets. It points to an oculus-like opening in the ceiling of the pilot chamber. The pilot is visibly fused to its chair, reaching 15 feet in height. [Fig.7] The pilot is has no legs, indicating that its sole purpose is piloting the ship.[Fig.8]

ENTRANCES

The entrances to the space craft are shaped like orifices and are not serviced by ramps or other elements for accessibility. They are situated three metres from the ground and roughly one to two metres in diameter. The entrances are primarily openings for intake and exhaust of air and other fluids. The Space Jockey Pilot, being significantly larger than the openings, indicates that the entrances are not mean to function as they would for humans but to act as service ducts for the greater body of the Space Jockey who had no need to leave its chair. [Fig.9]

FLOOR

The floors are lined with an organic matter in a skeletal configuration. The artist H.R. Giger designed the set with bones. The audience can speculate that if the Space Jockey had been alive, the walls would be animated and pulsating to service, and contain the thinking Space Jockey life forms. Without any ramps or accessible staircases, the floor is left uninhabited by life forms other than its prey.

(Left) Wreck, H.R. Giger (1978) **[Fig. 4.8]**

(Centre) The Space Jockey, Aliens Apocalypse: Destroying Angels (1999) **[Fig. 4.9]**

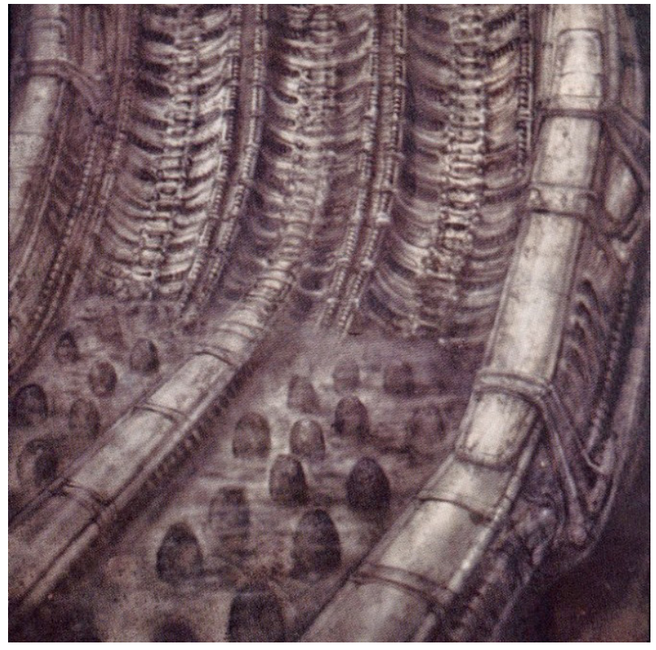
(Right) Egg Chamber, Work 386:Egg Silo Version 3. H.R. Giger (1978) **[Fig. 4.10]**

EGGS

The reproductive part of the derelict ship is a cargo space filled with eggs. [Fig.10] There is an energy field veiled over the eggs so that they remain dormant until their prey arrives. When the energy field is deactivated or unintentionally breached, their outer layers of skins containing both thermo- and pressure- sensitive veins, hatch a creature to subdue the prey. This strange entity is the Face Hugger whose sole purpose is to implant another aliens species, ensuring the survival of its kind.

CONCLUSION

The derelict spacecraft and its spatial composition establishes a world based upon an interconnected relationship between humans and a built environment. The result is a world where humans are fuel for the survival of an alien species. This speculative scenario of the future is relevant to the thesis because it is about humans being entirely consumed within their built environment. This situation is an extreme example of when humans are no longer the central focus of life in the universe.



BLADE RUNNER 2049 (2017)
DIRECTED BY DENIS VELLENEUVE
A DYSTOPIC ECOLOGY

PREMISE

The world in the film Blade Runner 2049 (2017) projects climate conditions which humans will face in the year 2049 in California, Earth. There is extreme environmental degradation due to over zealous industry and over population. This has left Earth with acid rain, resulting in barren lands and toxic waters. Cities are also scarred by endless wars, leaving radioactive dust throughout them. The ability to travel to other somewhat habitable planets known as Off-Worlds, has that prompted the United Nations to encourage people to emigrate. The world conditions of Blade Runner 2049 are the consequences of human inadequacy to care about life on Earth. The following text examines three locations and their spatial composition and atmosphere as influenced by extreme environmental neglect and war.

CALIFORNIA, 2049

Los Angeles, California, in 2049 is a fully urbanized and overpopulated city dominated by Tyrell Corporation's buildings that tower several thousand metres into the atmosphere. Airborne vehicles for transportation criss-cross the auto-navigated skylines. At ground level, Los Angeles is depicted with artificial light and extremely self-indulgent people. The border of the city is guarded with flood gates against impending hurricanes and flooding. The city is very hot and experiences a lot of rain.

EXTREME HEAT

The sky is constantly blocked with suspended particulates in the atmosphere that decrease visibility and increase ground-surface temperatures. Buildings and other concrete surfaces in the area retain heat produced by solar radiation during the day, which is released during the night.

(Below) City Outskirts, Blade Runner 2049 (2017) [Fig. 4.11]

(Facing page top) City Outskirts at the Farm, Blade Runner 2049 (2017) [Fig. 4.12]

(Facing page bottom)Las Vegas and radioactive dust, Blade Runner 2049 (2017) [Fig. 4.13]

The sun heats up the heavily urbanized Los Angeles through direct sunlight and heat re-emitted from the ground after the Earth's atmosphere has absorbed solar energy.[2] Heat is re-emitted through various physical processes like radiation, convection, and turbulence, making the ground plane the warmest part of the city. Gases like carbon dioxide hinder the dissipation of heat from the city, and greenhouse effects ensure the increase of average surface temperatures.[3]

The water cycle of the region is altered, as depicted by scenes where it is constantly raining. Perpetual evaporation from a warmed ocean causes torrential downpours. Higher air pressures influenced by heat over surrounding bodies of water alter water and air movements, which result in more frequent and intense hurricanes.[4] By this time, the polar ice caps will have completely melted, giving rise to mean sea levels.[5] The need for flood barriers around the city in Blade Runner 2049 is justified.

The film takes place after World War Terminus, a war involving nuclear weapons and the world's most powerful nations. The war ends after successive nuclear bombs have laid waste to Earth's surface, resulting in an empty Las Vegas tainted with radiation. The city is left in ruins with the desert sand creeping into the city. There is an inactive city infrastructure, powerless buildings and orange radioactive dust flowing throughout the city, making it uninhabitable.

After the detonation of many nuclear bombs, a prevalent climatic after-effect is nuclear winter.[6] Smoke from the fires caused by the bombs would be heated and lofted into the Earth's atmosphere and then spread throughout the entire world, lasting for years. The surface of the Earth would become dry, such that a location like Las Vegas would be increasingly dry and void of crop growth. Oxides released from the nuclear bombs would carry into the upper atmosphere and deplete the protective ozone layer, resulting in an increase of ultraviolet radiation for the Earth's surface. Bombs of such a magnitude would deplete ozone levels by 70% severely burning the Earth's surface and life on it.[7]

Another environment projected for California in 2049 is depicted on the outskirts of the city. It is shown as a wasteland with a single tree that has died, requiring cables to help keep it standing. There is a farm without relation to its natural surroundings that produces genetically incubated and modified grubs indoors. The outskirts are also absent of wildlife with little vegetation, massive amounts of garbage overflowing the land, and decrepit machinery everywhere.

An environment such as the outskirts of Los Angeles experiences little to no rain. A heavily urbanized state of California, consisting of concrete and non-natural materials, would not transpire and would influence neighboring low inland areas of the continent to become dry. Water from the ocean would transpire and fall on the nearest and high buildings in Los Angeles. Thus, the mean surface soil moisture in such a future scenario would drop roughly 2mm resulting in devastated wildlife, ecosystems, and the materials necessary to sustain life.[8]

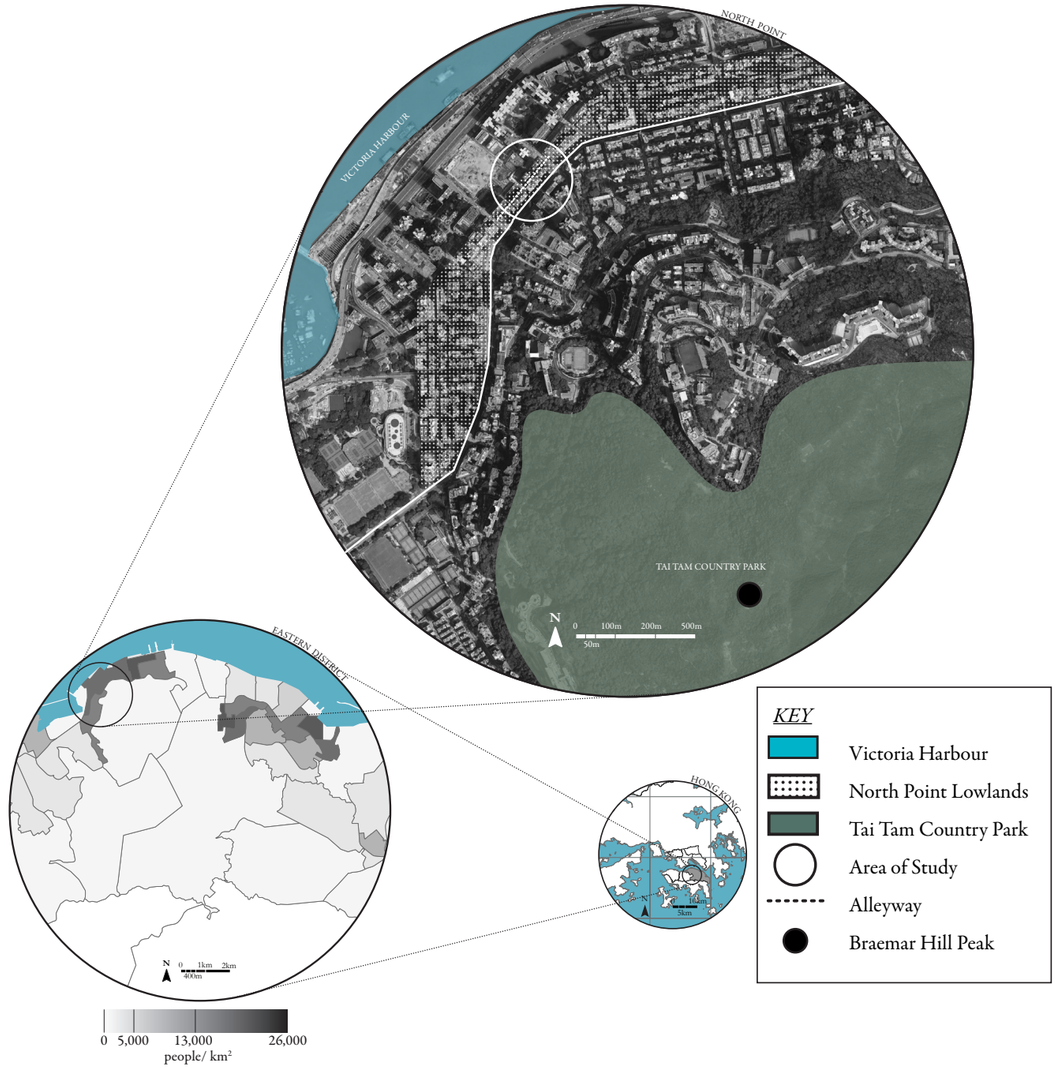
The film projects the future environmental conditions of Los Angeles in 2049 by extrapolating current conditions of global warming. It is interesting to be able to visualize these conditions, so that we are able to experience such claustrophobia both spatially and psychologically. The film posits ideas about a desperation for survival such that humans start to exploit the use of biological slave labour, substandard living conditions, and the option to live on another planet. This film raises awareness of the effects of environmental neglect.

(Facing page top) California, Blade Runner 2049 (2017) **[Fig. 4.14]**

(Facing page top)Los Angeles at night, Blade Runner 2049 (2017) **[Fig. 4.15]**

END NOTES

1. A Cyberbrain is a human brain that is physically integrated with electronic components to produce an augmented organ. Cyberbrain implants allow the brain to interface with the Internet and have a direct and constant connection to computer networks and other individuals who have a Cyberbrain. The Cyberbrain rids the need for any type of external device allowing for a seamless and augmented mental capacity of humans.
2. Hong Kong Observatory. "Causes of Climate Change." 2016. http://www.weather.gov.hk/climate_change/human_activities_e.htm.
3. Hong Kong Observatory. "Global Warming: The Hong Kong Connection." Government of Hong Kong Special Administrative
4. Erickson, Kristen. "How do Hurricanes Form?" NASA Space Place2016. http://spaceplace.nasa.gov/hurricanes/en/.
5. Tong, Hang-wai. "Under the Influence of Global Warming, are Tropical Cyclone Activities Changing?" Hong Kong Observatory2016. http://www.weather.gov.hk/education/article_e.htm?title=ele_00276.
6. Robock, Alan. "Nuclear Winter." 1, (May/June, 2010): 418.
7. National Science Digital Library. "Ozone Depletion." . Accessed 10, 2017. http://www.atomicarchive.com/Effects/effects22.shtml.
8. Hong Kong Observatory. "Hong Kong in a Warming World, Second Edition." Government of Hong Kong Special Administrative Region. http://www.weather.gov.hk/climate_change/climate_change_e.pdf.



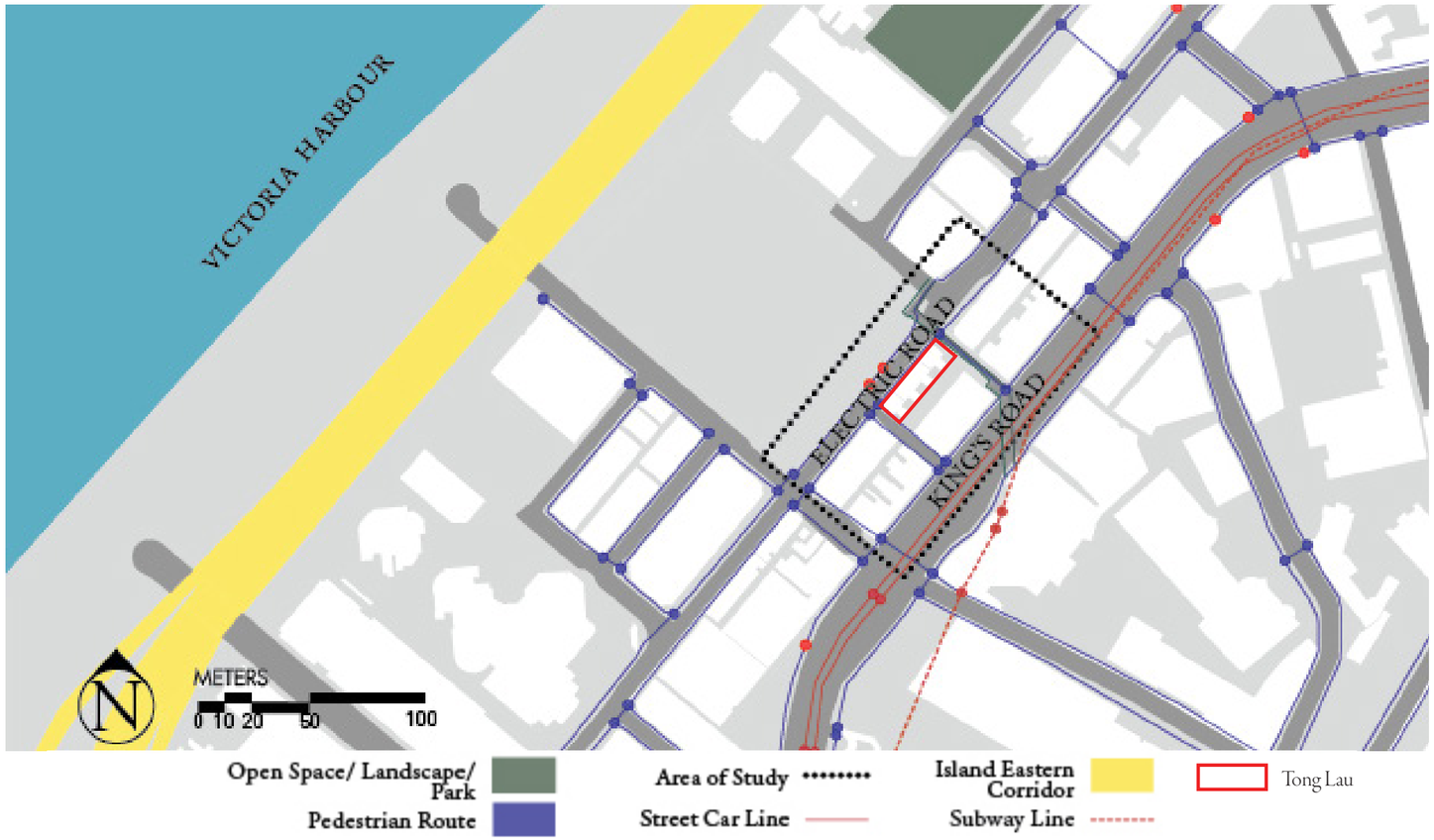
[Fig. 5.1] (Top) Site images - View from Braemar Hill

[Fig. 5.2] (Bottom) Shrowded Historic Chinese Shophouse in NPL

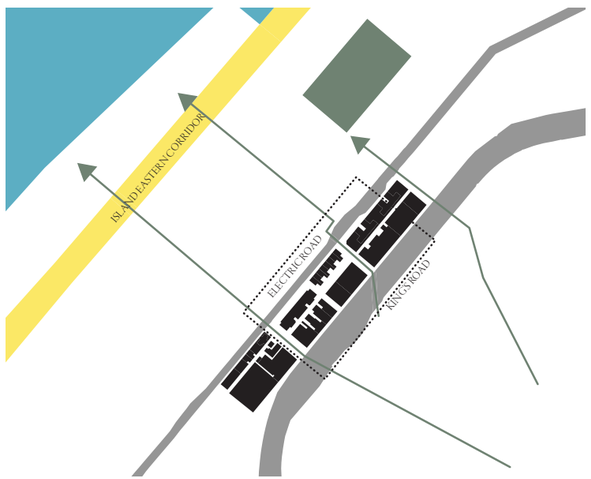
[Fig. 5.3] (Right) Site map of Hong Kong Island, Eastern District and the North Point Lowlands

05 DESIGN PROPOSAL

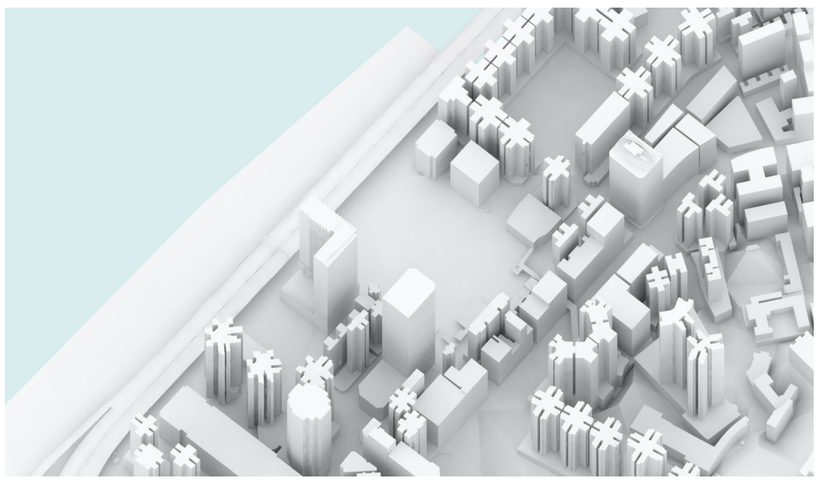
On the island of Hong Kong, a co-generated public space is proposed. The subject site is in the district of North Point, between Electric Road and King's Road. [Fig. 5.4] This location is a mixed-use urban area that is part of the lowlands in Hong Kong. (Lowlands – terrain between the harbour waters and reclaimed land at the base of Hong Kong's steep, excavated, and mountainous slopes.) At a larger scale, the North Point Lowlands (NPL) is part of a process of land reclamation and rehabilitation on the island of Hong Kong. Its northern shores, bordering the Island Eastern Corridor, are comprised of synthetic reclaimed land, created from Victoria Harbour to provide its land for new homes.[1] Directly south of NPL is terraced housing. Beyond is Tai Tam Country Park, which occupies one fifth of Hong Kong Island's land area. The park is a protected and naturally preserved landscape that has been under systematic reforestation to revive its badly eroded hills after WWII.[2] [Fig. 5.3] Thus, NPL's unique in-between location demands that any proposed project in the area must be sensitive to the acts of reclamation and rehabilitation taking place both within and to the north and south of it. To this end, the project aims to engage natural, synthetic and social site features by reinvigorating a dormant alleyway in NPL with grafting qualities of geotextiles to become a more inclusive, connective, and sensitive space. [Fig. 5.2] This new vibrant public space will allow people to stop, rest, and re-engage the frenetic city, while also connecting inhabitants with physiological perceptions of site energy, that is, the creation of an expanded human physiology in North Point Lowlands.



[Fig. 5.4] General circulation and program diagram



[Fig. 5.5] Access to harbour and country park



[Fig. 5.6] Axonometric of North Point Lowlands, Hong Kong

REHABILITATION AND COHERENCY

The urban fabric of Hong Kong finds its roots at North Point Lowlands, such that the very first settlers depended on its proximity to Victoria Harbour for trade, fishing, and transportation. The beginnings of NPL were comprised of entertainment centres, theatres, large mixed-use towers, and vernacular shop houses known as Tong Lau.[3] The presence of Tong Lau provides cultural and geographical distinction to neighbouring cities. Some of the oldest shophouse vernaculars are constructed in this area of Hong Kong Island, the root of Hong Kong's social fabric. This makes NPL a prominent location for intervention. This site differs from other locations in that its historic city framework operates in conjunction with geotextile structures by extending inhabitant sensibilities with architectural components. They allow for a deeper inhabitant connection to the site by bringing to light specific qualities. The subject site features a historic tenement house bordering Electric Rd. [Refer to Fig. 5.3 & Fig. 5.4] Thus, the intervention attempts to make coherent the existing urban fabric. Strategies include bringing the bifurcative and emergent qualities of spring, a breath of inspiration, and community gathering as gestures of rehabilitation. This design proposal is a thoughtful addition that creates coherence to its neighboring reclaimed and rehabilitated synthetic and natural land features to the north and south respectively.

SITE FEATURES

The North Point Lowlands is an area located north-west of Siu Ma Shan, a 200-metre tall hill on Hong Kong Island. Existing site features include: a small parkette 50 metres north [Fig. 5.4, green geometry], a new residential development to the northwest, and subway access 50 metres to the south [Fig. 5.4, dotted red line]. Immediately to the north is the Island Eastern Corridor, a highway that runs along the shore line of Hong Kong Island [Fig. 5.4, yellow geometry]. There is a historic rail-car line located on the primary arterial route called King's Road [Fig. 5.4, solid red line]. Secondary streets run through the area towards Victoria Harbour. A tertiary street, Electric Road, runs parallel to King's Road, which circulates travellers north-east and north-west. There is ample space for pedestrian circulation along Electric Rd., King's Rd., and connecting streets [Fig. 5.4, blue line]. Oil Street directs travelers toward the coastline of Victoria Harbour and serves as a remnant of the land's former connection with Victoria Harbour. [Fig. 5.5] [Fig. 5.6]

BORDERING SITE FEATURES

NPL is a part of the North Point district on Hong Kong Island with a population density of approximately 26,000 people per square kilometre.[4] Bordering North Point to the west is Causeway Bay, a major bustling commercial destination. To the east is Quarry Bay, a predominantly residential area with office towers. Roughly one kilometre to the South is Tai Tam Country Park, and within it is Braemar Hill, located at the northern tip of the park. Braemar Hill also offers a view of the concrete jungle that is Hong Kong. [Fig. 5.3] [Fig. 5.1]

[Fig. 5.7] (Top) Site images - North Point alleyway

[Fig. 5.8] (Bottom) Alleyway vegetable street vendor

[Fig. 5.9] (Right) Alleyway collage rendering

THE PENCIL TOWER AND ALLEYWAYS

The incredibly dense urban core of Hong Kong has produced a unique housing type known the pencil tower. Residential pencil tower typologies are supported on podiums that contain retail and commercial amenities at NPL. Street level is met with ample pedestrian and vehicular traffic. Servicing between King's Road and Electric Road are alleyways between building podiums. [Fig. 5.5]

The NPL alleyways are less densely populated public spaces compared to its immediate urban context. They allow for air to circulate between residential towers and for light to enter between buildings.[5] Typically, they are characterized by unexpected, locally organized vendors who offer commercial services such as the sale of small amenities, vintage barber shops, storage compartments, vegetable stands, fabric and tailor shops, and other services.[6] Not evident in these public alleyways are commercial urban fabrics. These vendors lend distinctive qualities to spaces not found in other areas of the world. Furthermore, the alleyways are often dark and tunnel-like, surrounded by a cacophony of piping and air conditioning units that drown out the sounds of street cars, taxis, and buses. The alleyways evolved from purely pragmatic spaces, which today have become locations for locals to set up shop or to rest.[7] [Fig. 5.7] [Fig. 5.8] [Fig. 5.9][Fig. 5.10]

A HEATED SITE

The design proposal is inspired by the influence of heat at the subject site.[Fig. 5.12] Throughout thesis research, it was evident that the Hong Kong Observatory has placed increasing awareness on the effects of global warming on Hong Kong and Kowloon.[8] Such attention is due to increasing average and mean temperatures of the island due to the heat island effect, whereby concentrated concrete structures and surfaces retain solar radiation during the day.[9] During the night, heat is released back into the ground and surroundings, so that night temperatures are generally higher than those in rural land areas. In addition, reduced visibility, increased cloud cover, pollution, and greater frequency of extreme weather events are worthy factors to be considered. [10, 11]

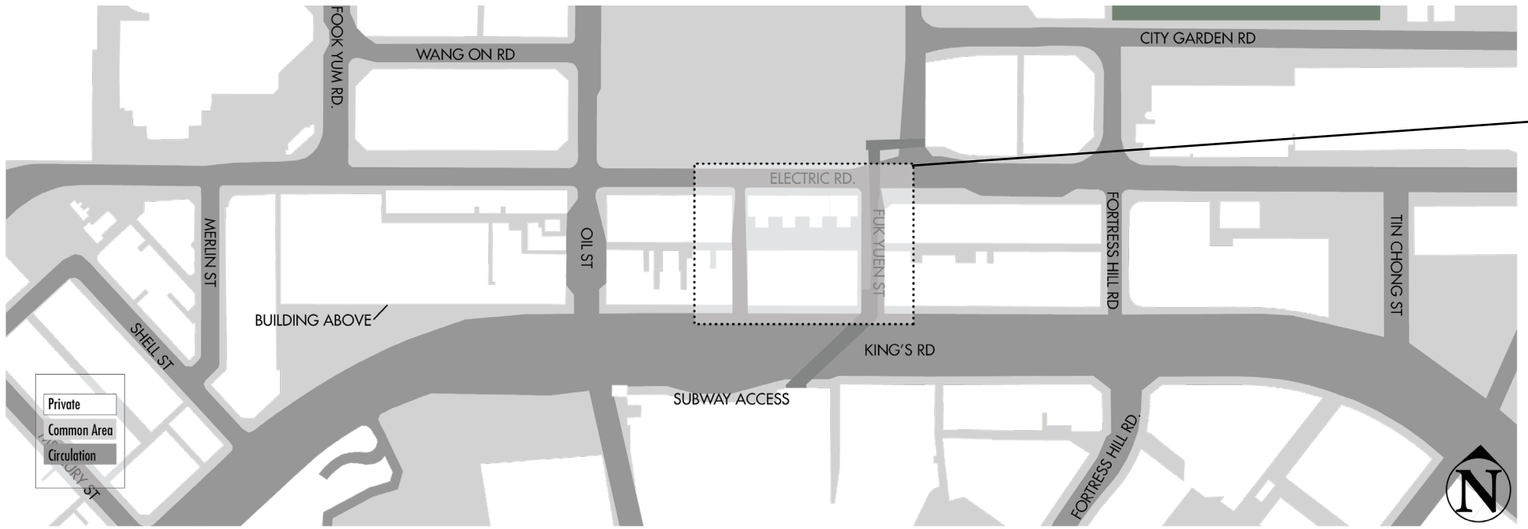
CLIMATE

The climate of Hong Kong is subtropical, with very mild winters and hot summers that are rainy and humid. The area's annual mean temperature is 28.5°C, with the summer solstice 10-15 degrees warmer and the winter solstice 5 degrees cooler. Humidity is high in this region with an annual average of 77%, with 2400 mm of average precipitation.

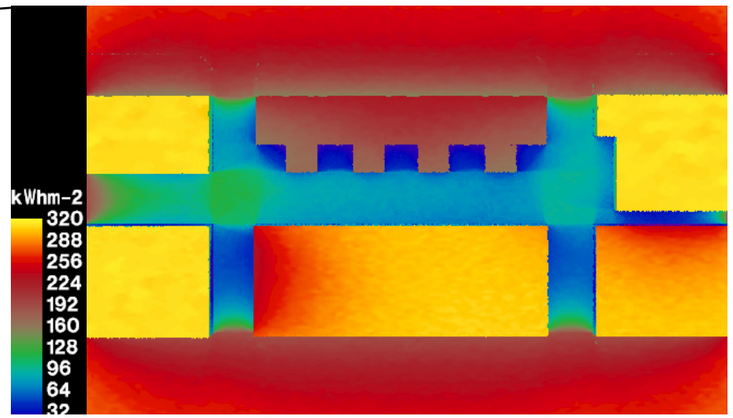
SPRING AND THE DESIGN PROPOSAL

The design proposal utilizes the effects of spring as a guide. Spring (March 21st to June 21st) is mild and pleasantly warm. The average hours of daylight number twelve. Temperatures reach a low of around 15°C with increasing temperatures and the occurrences of the year's first thunderstorms. In May, the area begins to warm with highs of 28°C. This temperature is lower in comparison to summer months. Rain during spring becomes progressively more significant throughout the months. An irradiance map displaying solar radiation accumulated in kWh/m^2 between the time frame of March 21st (0600hr - 1800hr) and June 21st (0600hr – 1800hr) is displayed below. [Fig. 5.11] [Fig. 5.12]

[Fig. 5.10] Typical alleyway



[Fig. 5.11] Site map

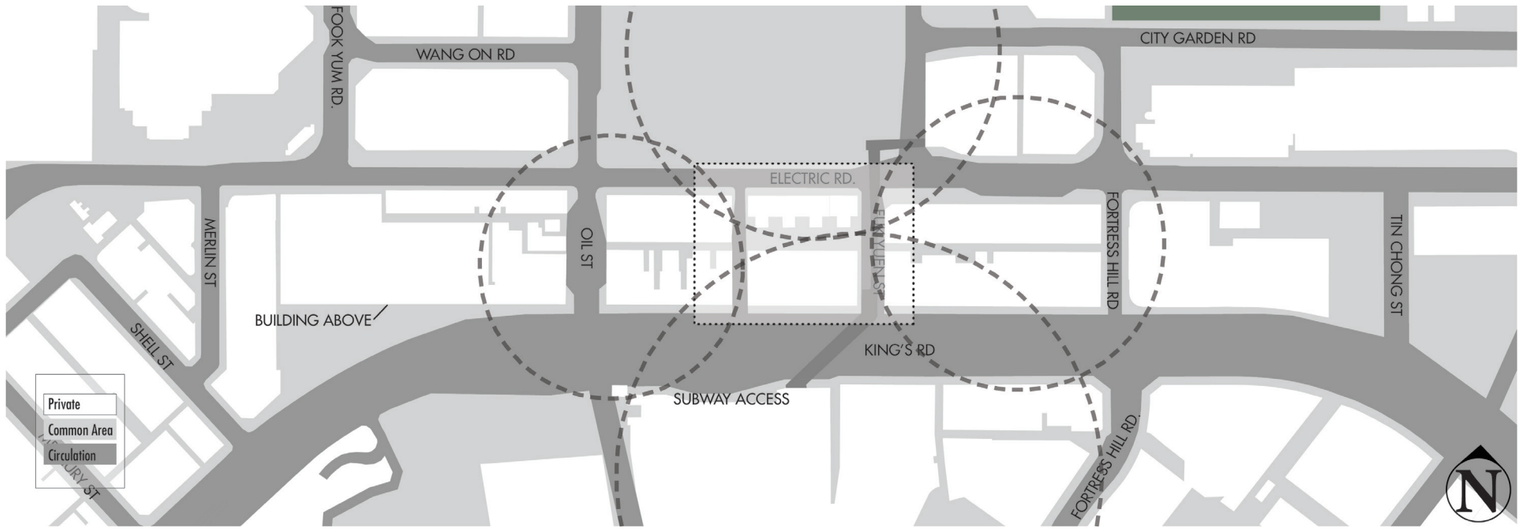


[Fig. 5.12] Irradiance map of area of study. Time frame - March 21st to July 21st, sunrise (6am) to sunset (6pm)

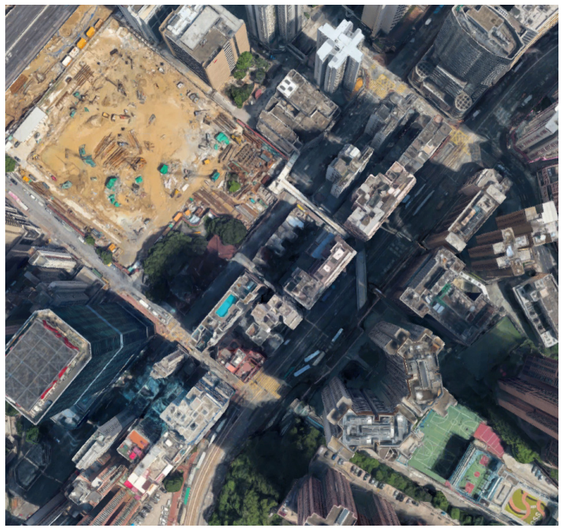
SITE INFLUENCES

Existing site features are dictated by physical structural components of apartment towers. [Fig. 5.13] A new rectilinear and radial structural column grid is proposed. This grid of columns, spaced eighteen metres apart, would line the sidewalk of King's Rd. and Electric Rd. [Fig. 5.16] The linear spaced columns provide the primary structural support of the proposed canopy structure. Another set of columns are radially organized according to surrounding neighborhood buildings, districts, and country parks to provide coherence. These four radially organized column sets are the primary support structures for Deployment Stations. The eastern column set corresponds to the district of Quarry Bay; the south corresponds to the district of Fortress Hill; the west refers to the district of Causeway Bay; and the north corresponds to Victoria Harbour. These columns attempt to draw a structural relationship with their surroundings. [Fig. 5.14]

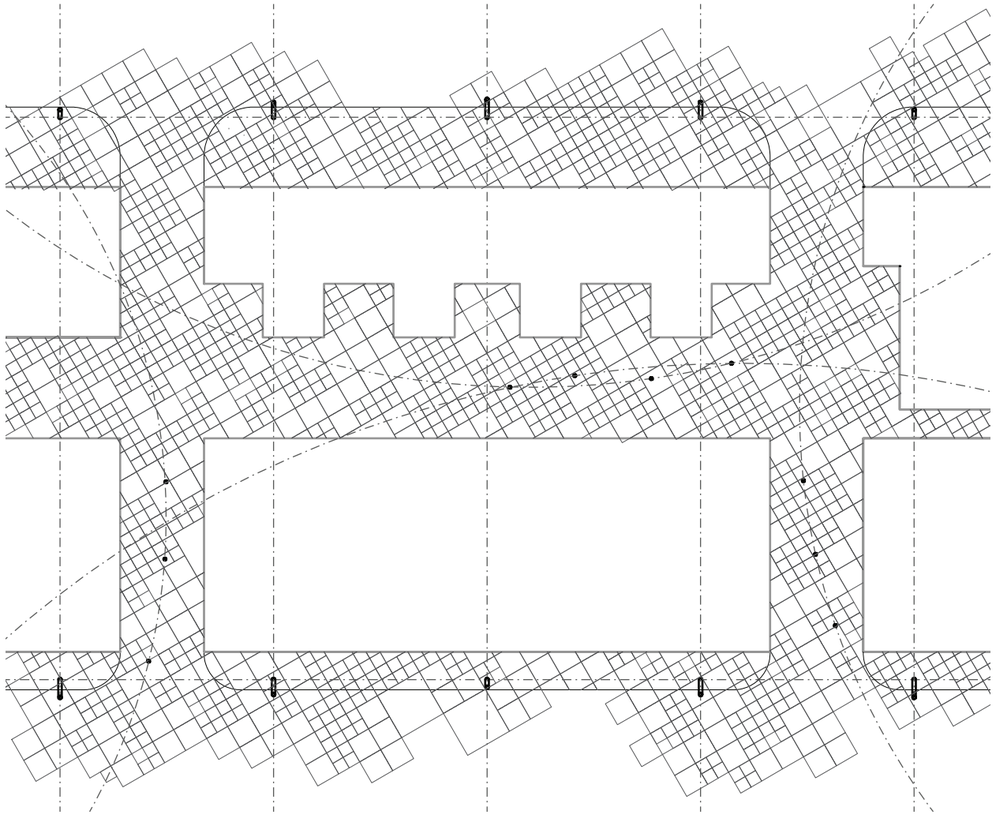
[Fig. 5.13] Regularity of apartment towers

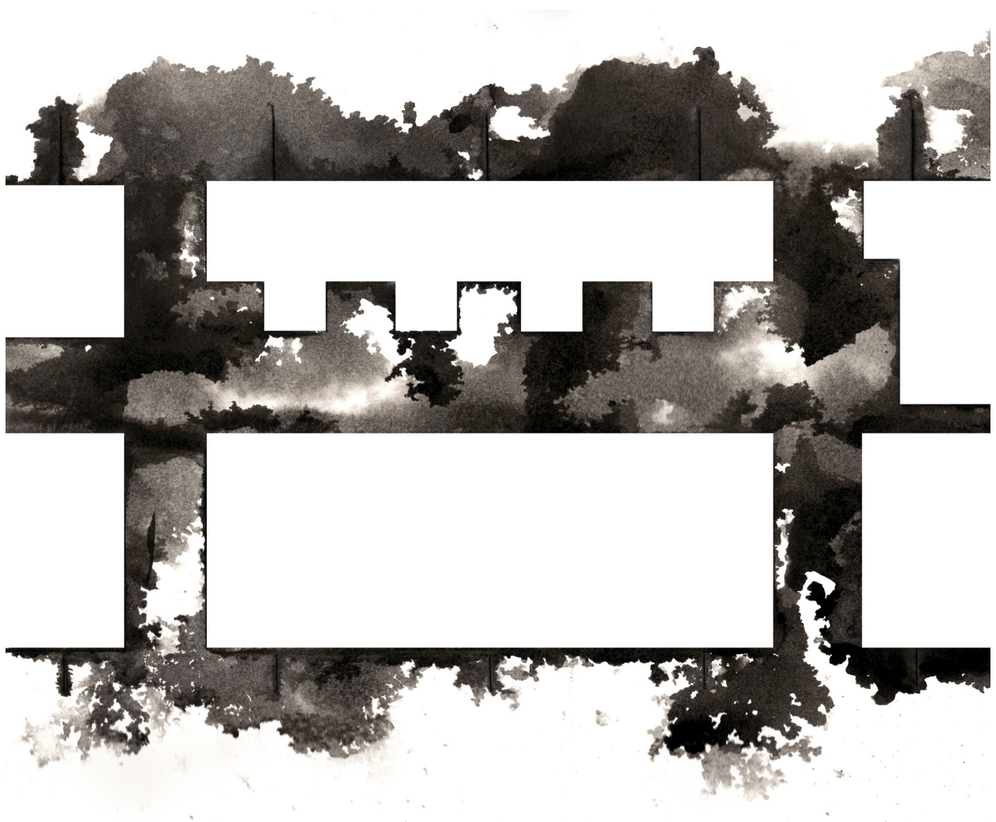


[Fig. 5.14] Site map with radial structural grid layout



[Fig.5.15] Birds eye view of the North Point Lowlands





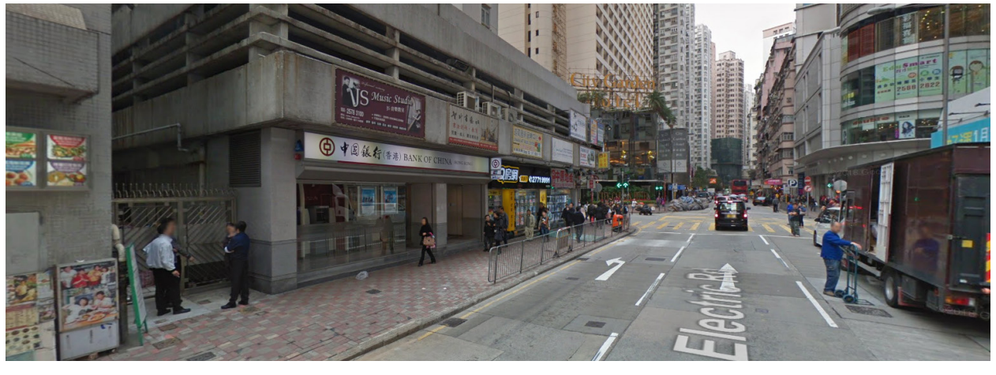
A MOMENT OF PERCEPTION

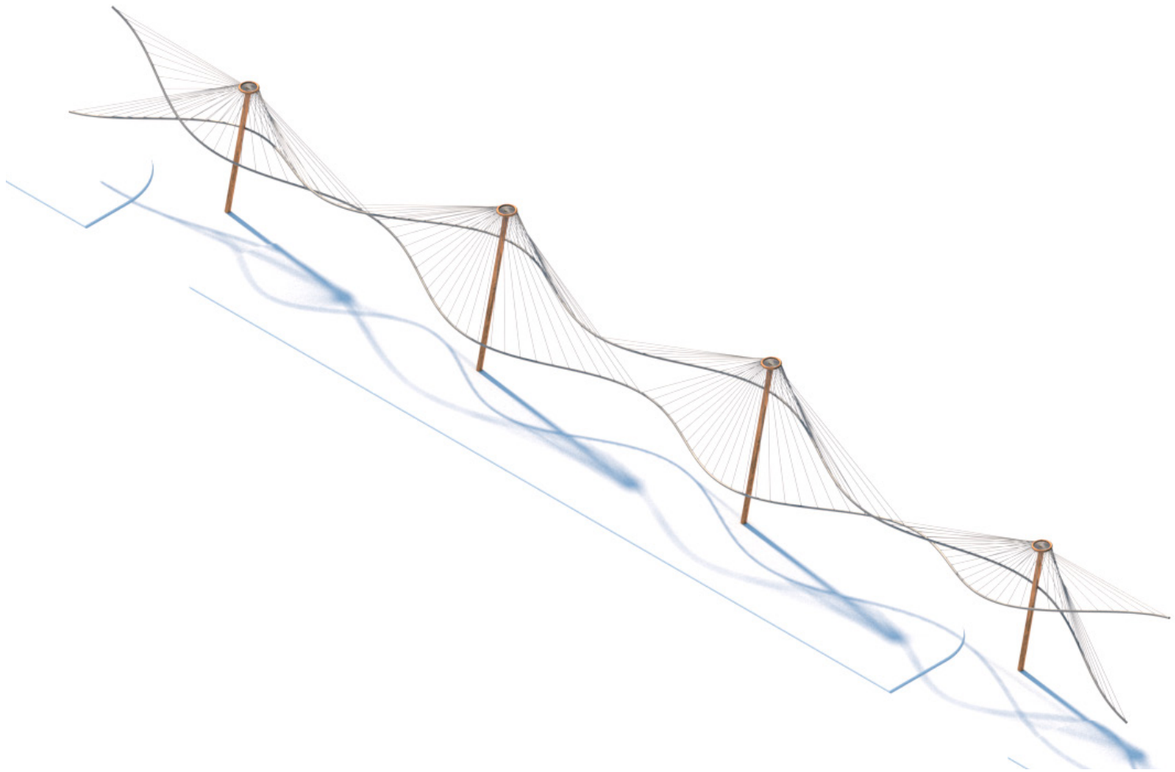
Latent heat energy flows throughout the study area. Black ink on card stock is used to represent a dynamic flow of fluid energy at the footprints of existing apartment towers. [Fig. 5.12] The flow of dense black ink is allowed to soak into the paper to quantify the dynamic action. The fluid leaves behind a trail of its movement giving evidence of a moment in which it materializes as a directed flow. This ink pattern is then translated into a quadtree pattern. [Fig. 5.17] Quadtree patterns are graphic filters that create nodes in a two-dimensional area. This simplification of data allows for complex patterns such as flows of liquids in two-dimensional space to be translated into a visual pattern. Moreover, this pattern is used to register heat energy at moment in time, which, in turn, generates a tiling pattern for the area of study.

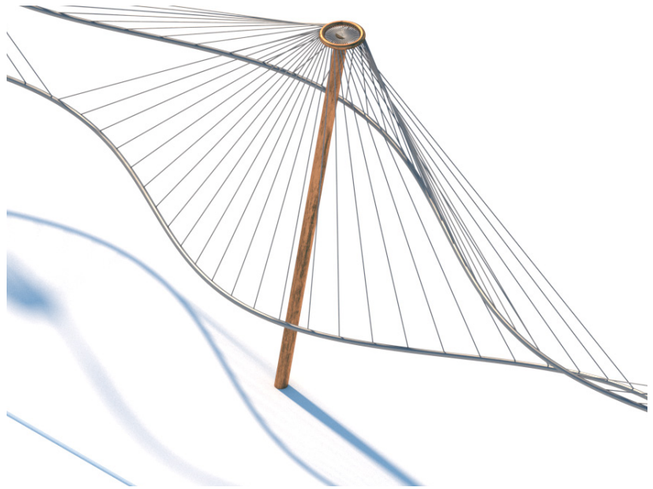
(Above) Quadtree geometric filter of fluid flows on site **[Fig. 5.16]**

(Facing page top) Black Ink and cardstock fluid flows **[Fig. 5.17]**

(Facing page bottom) Street view of the North Point Lowlands **[Fig. 5.18]**





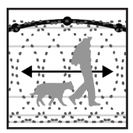


PRIMARY STRUCTURE

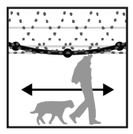
The primary structure consists of two sets of four steel columns spaced eighteen metres apart along the side walks of King's Rd. and Electric Rd. respectively. These steel columns suspend steel cables that pull, in tension, a hollow structural steel tube (HSS tube). This HSS tube acts as the selvage of the entire canopy. A selvage, in terms of fabrics, is an edge produced on woven fabric during manufacture that prevents it from unraveling.[12] When viewed in elevation, the HSS tube takes the form of an arch. [Fig. 5.51] When viewed in plan, a sinusoidal wave is seen. [Fig. 5.47]

(Above) Array of columns aligned along King's Rd. provide the primary structural supports to the canopy **[Fig. 5.19]**

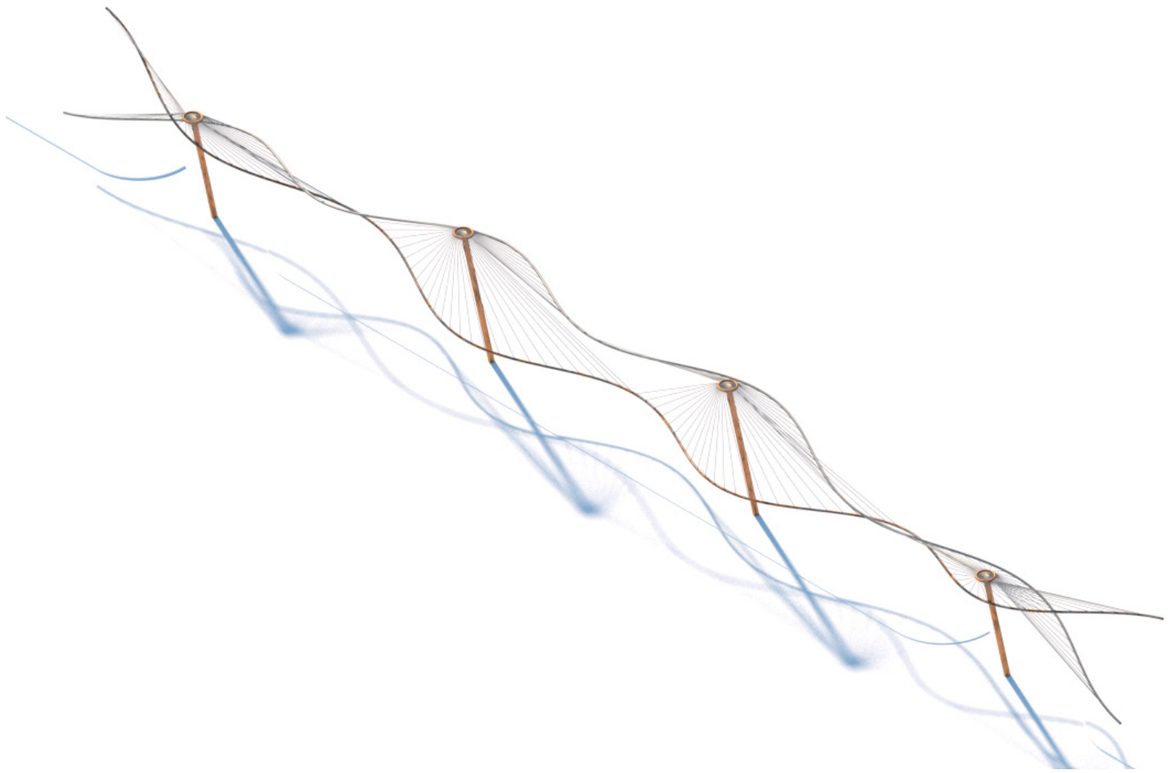
(Right) A single column tilted at 12.8 degrees provides shade for pedestrians waiting for a taxi, or resting while also creating views to the sky and support for the canopy **[Fig. 5.20]**



A pedestrian walking with matter orbiting radially while generating a concave curve.



A pedestrian walking with radial matter orbiting radially the body at a distance while generating a convex curvature.

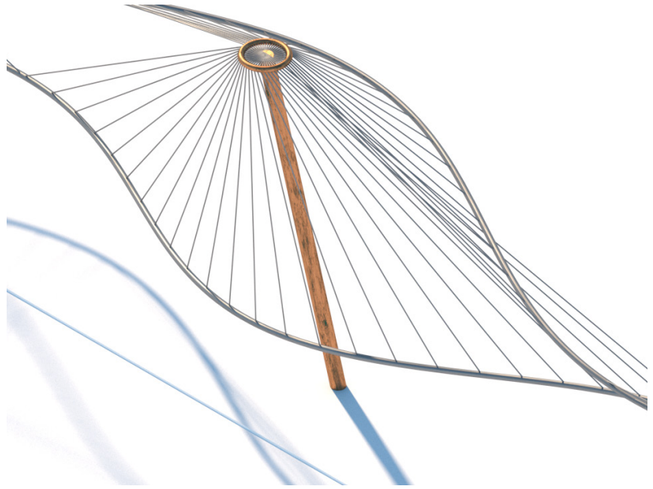


BRACHISTICHRONE CURVATURE

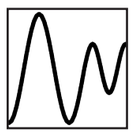
The arch of the HSS tube is inspired by cycloid geometry, also known as a brachistichrone curvature.[13,14] For instance, a cycloid is drawn by a rotating wheel with a point at its circumference. The resulting arch is a cycloid, which yields special physical properties discovered by John Bernoulli in 1694.[15] This curve, along which a body, subjected only to the force of gravity, will slide (without friction) between two fixed points in the shortest time possible.[16] Similarly, a constantly rotating wheel also creates an arch of a cycloid. The elevational cycloid or brachistichrone curvature is used to create a dynamic relationship between pedestrians and structures in the proposed canopy arrangement. As one passes under the HSS tube selvedge, the static curvature transforms.[17] [Refer to elevation view, Fig. 5.51]

(Above) Array of columns aligned along Electric Rd. provide the primary structural supports to canopy **[Fig. 5.21]**

(Facing page right) A single colum tilted at 12.8 degrees provides shade for pedestrians waiting for a taxi, or resting while also creating views to the sky and support for the canopy **[Fig. 5.22]**



A sinusoidal wave illustrating the rhythm of human breathing.



A sinusoidal wave illustrating maximal inspiration, maximal expiration and regular breathing rhythm.

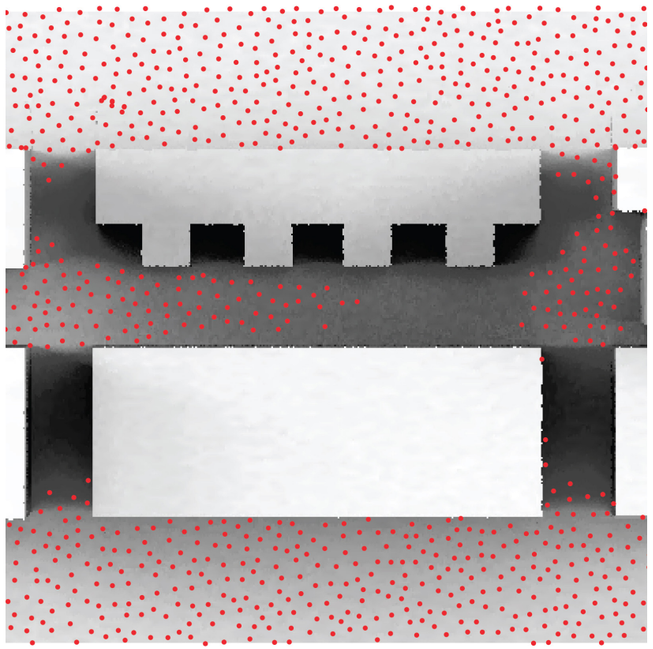
INSPIRATION (BREATHING)

Furthermore, the curvature of the HSS tube refers to the rhythm of human breathing. In terms of human physiology, vital capacity refers to the amount of air that can be moved through lung airways by maximal inspiration, which is then followed by a maximal expiration. This volume of air, cycling in and out of the body, influences the geometry of a cycloid arch.[18] This is done by applying a sinusoidal wave to reflect a rhythm generated by human breathing. Tidal volume, the amount of air moving through lung airways during normal breathing, is translated into a sinusoidal curvature of the primary HSS tube selvedge. Breathing inspiration is sculpturally represented with multiple amplitudes and is reflected within the canopy structure. [Refer to plan view, Fig. 5.47]

UNDER THE CANOPY

The resultant geometry of the primary structure creates spaces where pedestrians can rest in shade or to be directed with views to the sky. These areas occur where the maximums of the sine curve occur. The column is positioned at a 12.8 degree angle from perpendicular to the floor to allow for resistance of tensional forces that act on the canopy structure, HSS tube, cables, and column. [Fig. 5.19] [Fig. 5.21]

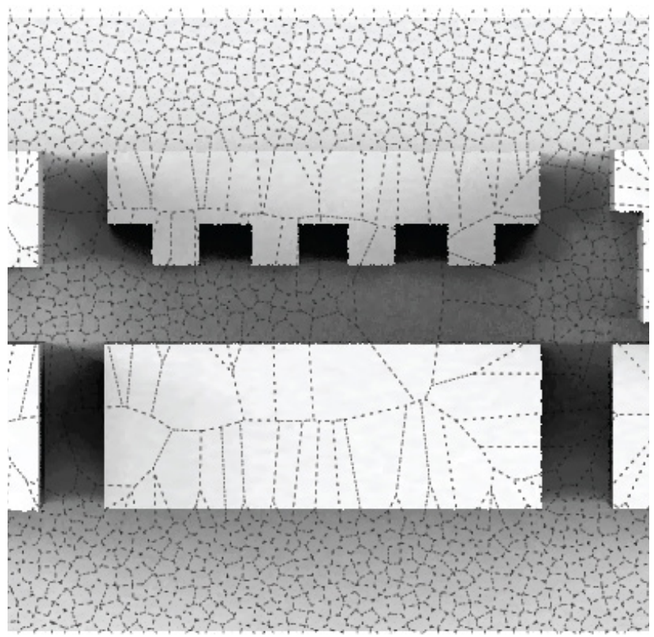
The multiple layers of the canopy act as a filter between the bustling podium towers and street level. The canopy renders energy flowing throughout the site with light and movement. Furthermore, the canopy is activated with varying densities of nodes and elongated nodes that create dappled views to the sky. Here, passersby connect by breathing, looking, touching, and simply being at the site. Their feeling of heat has co-produced a canopy that directs light and its intensity to fill the streets. The



[Fig. 5.23] **(Left) Image stippling of irradiance map**

[Fig. 5.24] **(Centre) Stipples correspond to cell sites of a voronoi diagram**

[Fig. 5.25] **(Right) Voronoi diagram and Delauney cell diagram with varying diameters of circles that correspond to intensity of solar exposure**



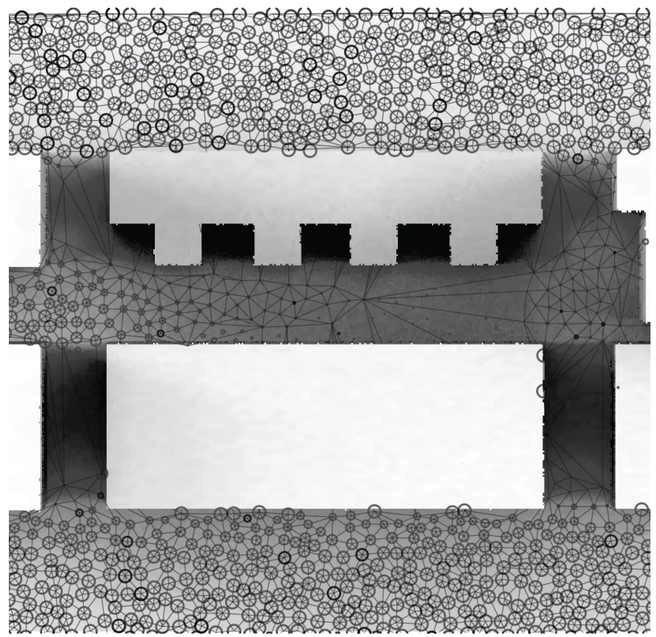
residential air space above the canopy flows towards the public streets and alleyways. Together, these flows of energies charge the canopy, rendering light.[19]

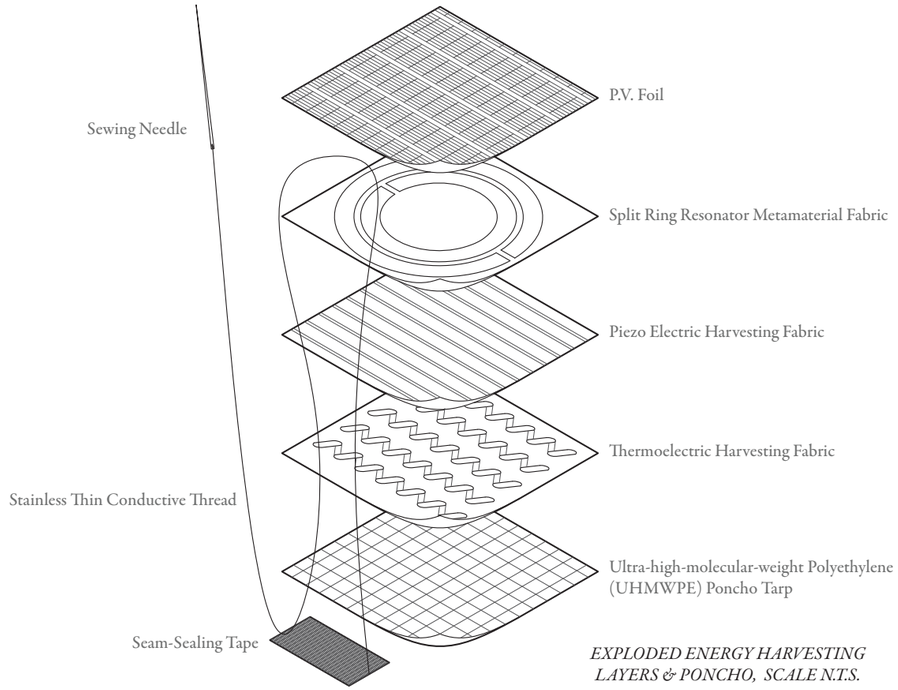
CANOPY DESIGN

Spring is metaphorically known to be related to rebirth, rejuvenation, renewal, resurrection, or regrowth. This time of the year is the beginning of many processes of life. The proposed canopy structure is informed by this season and embodies these natural processes. The canopy is activated by the Sun, Earth's greatest energy source, such that it infiltrates the area in new ways during spring.

A canopy structure is generated in response to the levels of solar radiation gained from March 21st (6am to 6pm) to June 21st (6am to 6pm). The irradiance map diagrams the amount of solar radiation gained throughout spring. The light areas of the diagram correspond to high levels solar radiation measured in kWh/m^2 and, opposingly, the dark areas of the diagram correspond to low levels of solar radiation gain. Stippling of the solar radiation diagram allows for solar radiation values to be translated into densities of stipples. [Fig. 5.23] High solar radiation values correspond to sparse stipples; low values are dense. These stipples serve as sites. Sites indicate a potential geometry that will influence surrounding parameters.[20]

Each site that corresponds to solar radiation gain at the area of study is connected creating a Delaunay tessellation.[21] Its corresponding Voronoi Cell diagram indicates a cell boundary that geometrically encompasses the surrounding site parameters. [Fig. 5.24] A circular geometry is applied to each site[22] that relates the density of surrounding sites and the circular geometry's radius. The resulting geometry responds to solar radiation values, while introducing two types of circular geometry in addition to site. [Fig. 5.25]





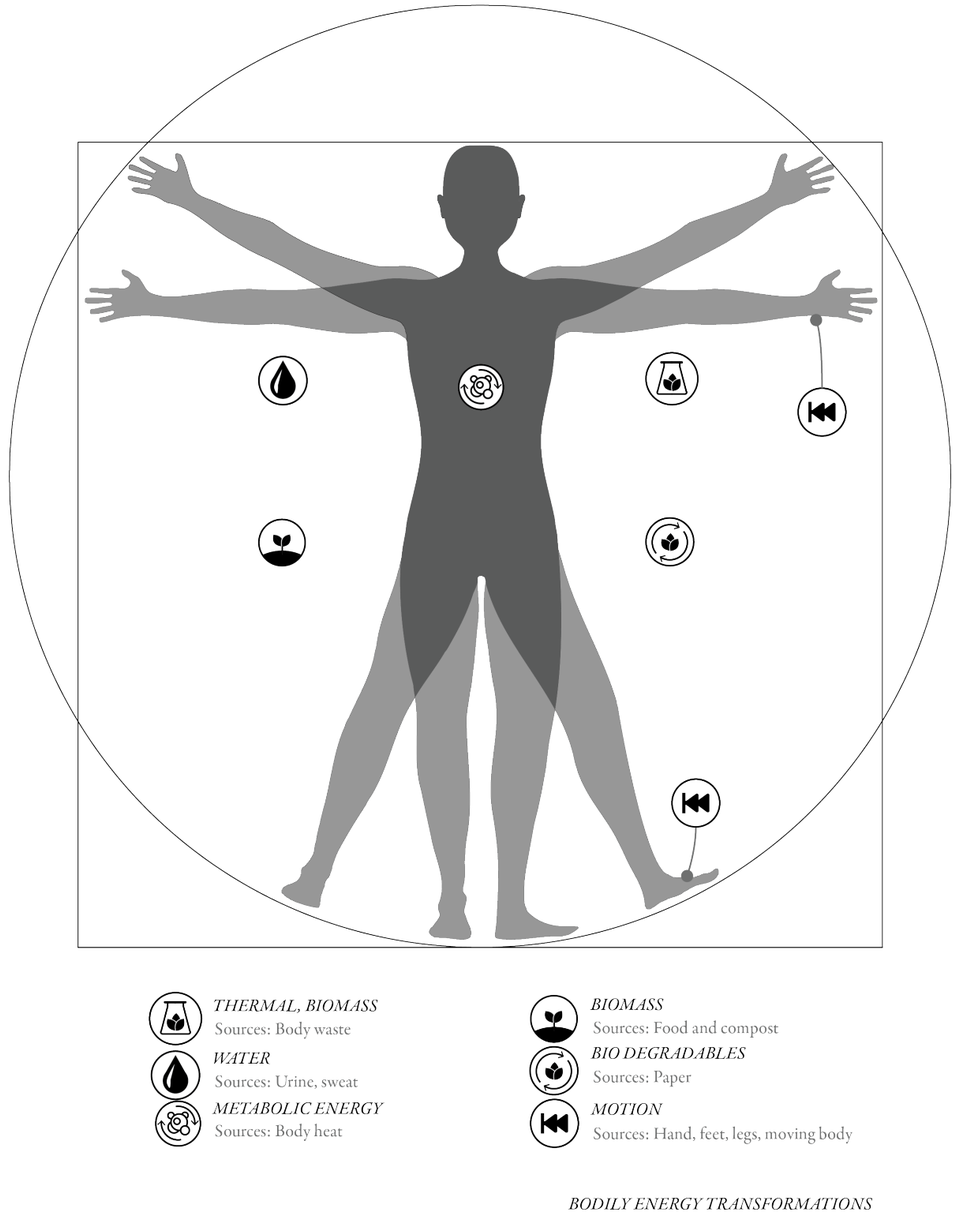
[Fig. 5.26] **Exploded hypothetical energy harvesting fabric layers (2017)**

A HYPOTHETICAL DEPLOYABLE GARMENT

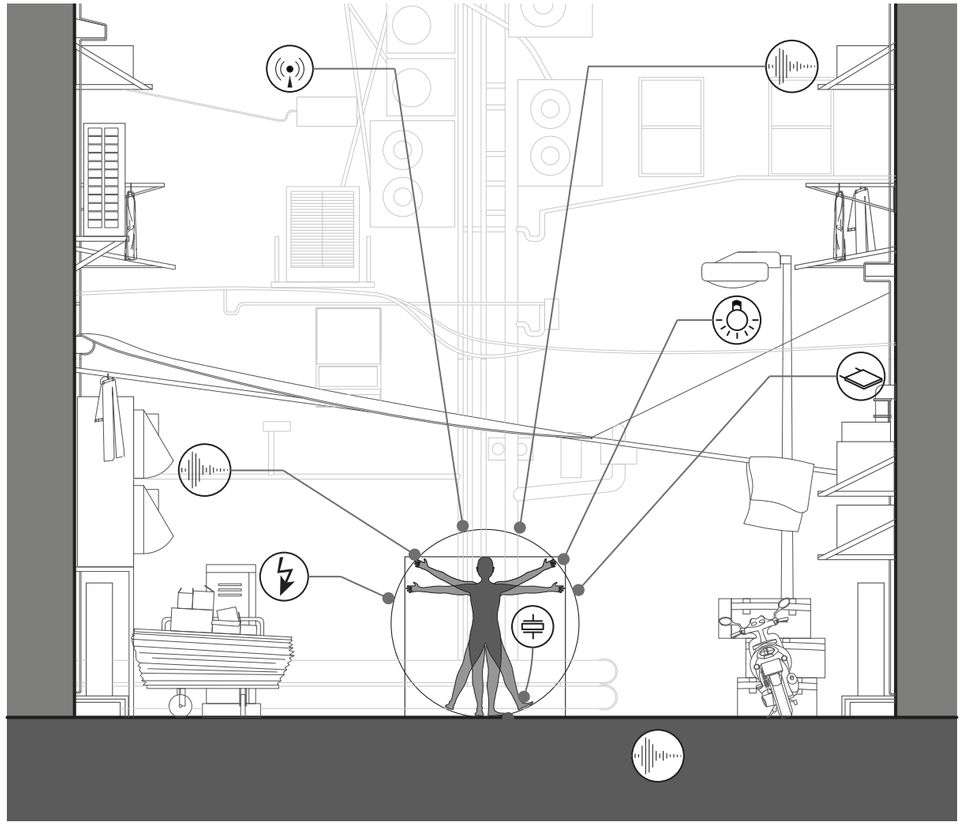
It is possible to speculate on the design of an outdoor active gear such as a poncho tarp.[23] Its functions act as a weather barrier, energy harvester, and deployable shelter. This multi-functional garment is the first line of defence against harsh elemental conditions, like rain, snow, wind, and sun. The hypothetical poncho tarp can be equipped with energy-harvesting fabrics, foils, and a hood for head protection. It can also be set up for shelter as a pentagonal tent.[24] A modular arrangement of cells of energy-harvesting materials are arranged for different functions of use. [Fig. 5.34]

ADVANCED ENERGY HARVESTING MATERIALS

In the context of the NPL alleyways and immediate surrounding environment, renewable energy inputs arising from solar radiation, water, radio, sound, voltage potentials, and kinetic energies can be harvested and stored into a battery.[25] [Fig. 5.26] Solar energies can be harvested with photovoltaic foils that are flexible and lightweight.[26,27] Rain can be used to clean solar cells, flush away waste from biomass burners and be purified for drinking.[28,29] Unpotable water with high tidal energy can be used to generate electricity with a satellite generator to store electricity in a battery for later use.[30] [Fig. 5.29] Furthermore, ambient radio frequency transmissions produced by urban environments can be harvested and transformed into usable electricity. [31] Piezoelectric materials that deform and exchange electrical energy due to sound vibrations generated by nearby street cars, railroad cars, subway trains, and other vehicles in the surroundings can be harvested. [32] Vibrating machinery from air conditioning units in the alleyways or ambient sound energy from trees are potential sources to be



[Fig. 5.27] **Bodily energy transformations (2017)**



SOUND/ VIBRATIONS
Sources: Vibrating machinery, A/C units, rail tracks, automotive machinery.

RADIO
Sources: Ambient radio transmissions, antennae

VOLTAGE DIFFERENTIALS
Sources: Electrical boxes, overhead wires, powerlines, high voltage lines

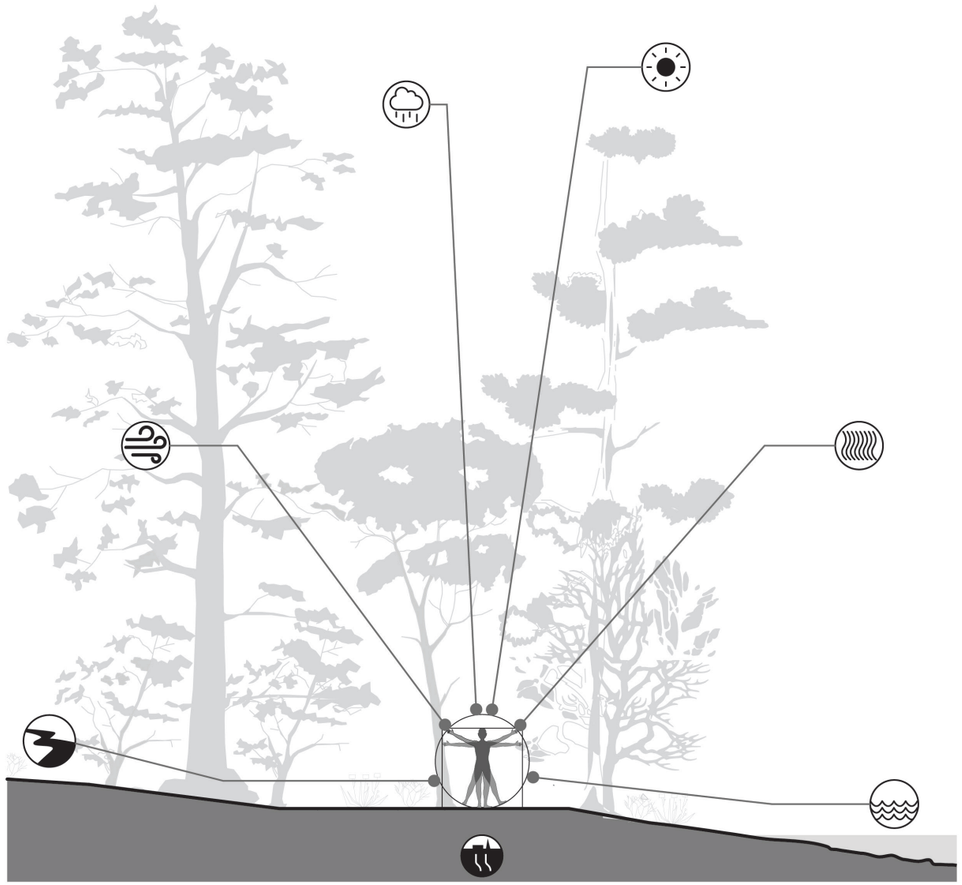
LIGHT
Sources: Street lights, automotive lights, building lights

MOTION
Sources: Human motion, automotive machinery

HEAT
Sources: Hot water pipes, heat byproduct from machinery, A/C units

TECHNICAL ENERGY TRANSFORMATIONS

[Fig. 5.28] **Technical energy transformations (2017)**



TIDES
Sources: Harbours, lakes, oceans, bodies of water

RIVERS
Sources: Freshwater streams, mountain streams, canals

GEOTHERMAL
Sources: Hot springs, hot dry rock

RAIN
Sources: Satellite generators and collectors

WIND
Sources: High wind zones, between buildings, areas with fabricated landmasses, movement in trees

SOLAR RADIATION
Sources: Daytime, low pollution zones with low air particulates

SOLAR THERMAL
Sources: Sun

NATURAL ENERGY TRANSFORMATIONS

[Fig. 5.29] **Natural energy transformations (2017)**

converted into usable energy.[33] Conductors held or placed as satellite generators can gather energy from high voltage lines around urban environments that are then stored in batteries.[34] Moreover, kinetic energy can be gathered from movements of the wearer such as clapping, stomping or jumping.[35] Ambient radio frequency transmissions produced by the city can be harvested and transformed into usable electricity.[36] [Fig. 5.28] Lastly, by-products of existing machinery, such as thermal energy, can be harvested with phase-change wax or salts that delay the temperature loss of a material.[37,38] Waste heat can be stored for later use.[39] [Fig. 5.27]

FUNCTIONAL GARMENTS

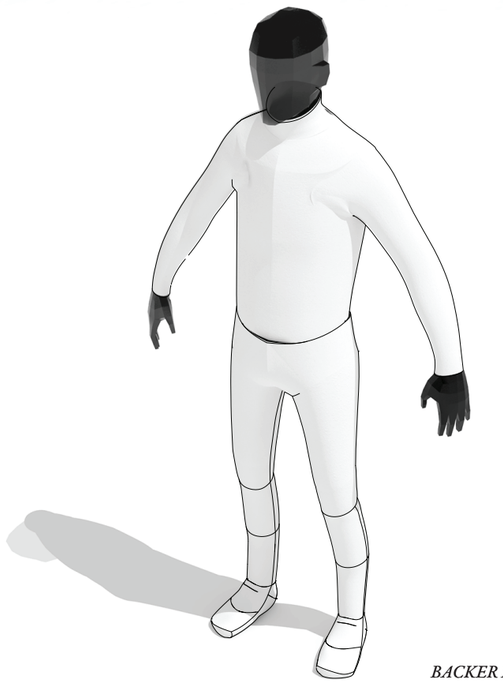
Ventilation and thermal control in active outdoor wear is accomplished with multiple layers with specific functions.[40] From the body to the exterior shell, the base layer is responsible for wicking sweat away from the body to keep it dry and warm. [Fig. 5.30] [Fig. 5.31]This base layer is constructed of sweat-wicking, drying and anti-microbial fibres like polyester and merino wool fabrics.[41] A shirt worn over top also has similar functions to the base layer; however, this layer adds warmth. A bug-shirt is used to protect the user from biting insects and ticks along with trekking pants or shorts depending on weather. A fleece is worn for added warmth. The main protective layer against the elements is the jacket, which is waterproof/breathable with

[Fig. 5.32] **(Above) Structural back pack support structure (2017)**

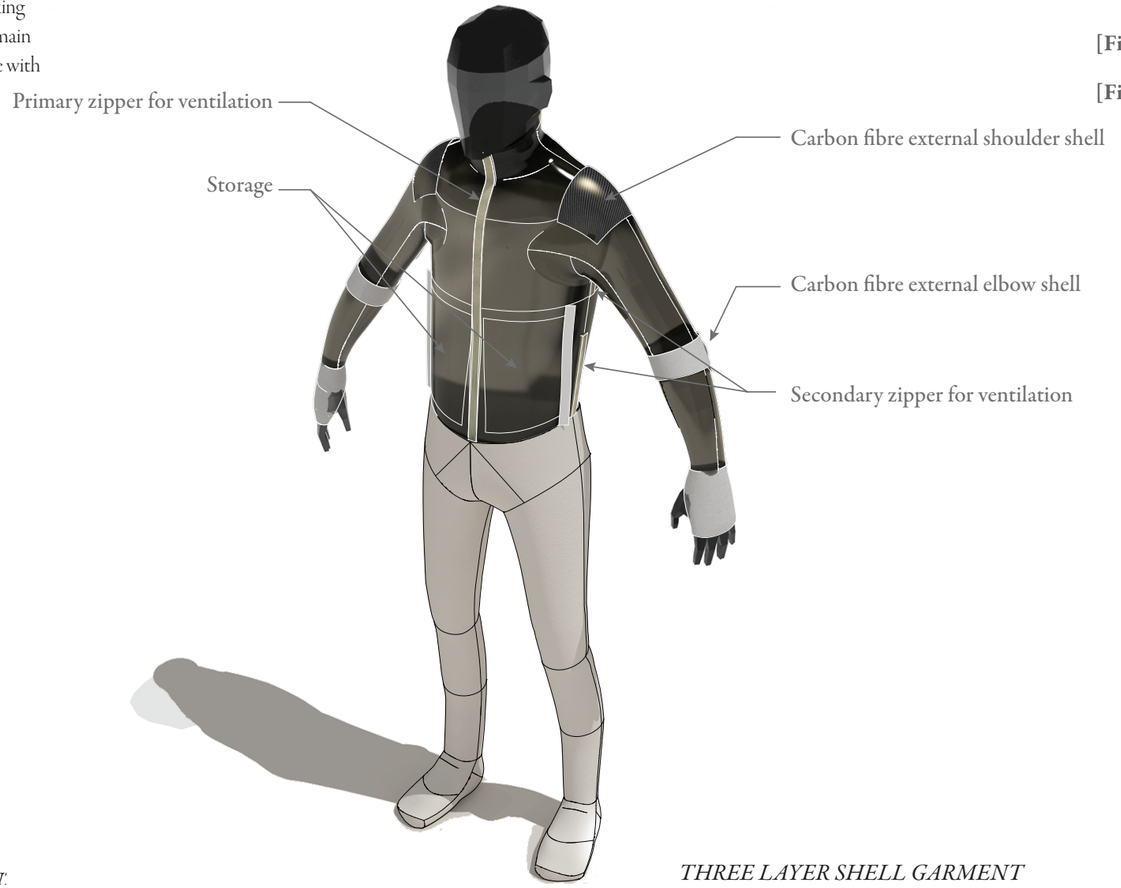
[Fig. 5.33] **(Below) Back pack shoulder and hip straps (2017)**

(Left) Backer layer garment (2017) **[Fig. 5.30]**

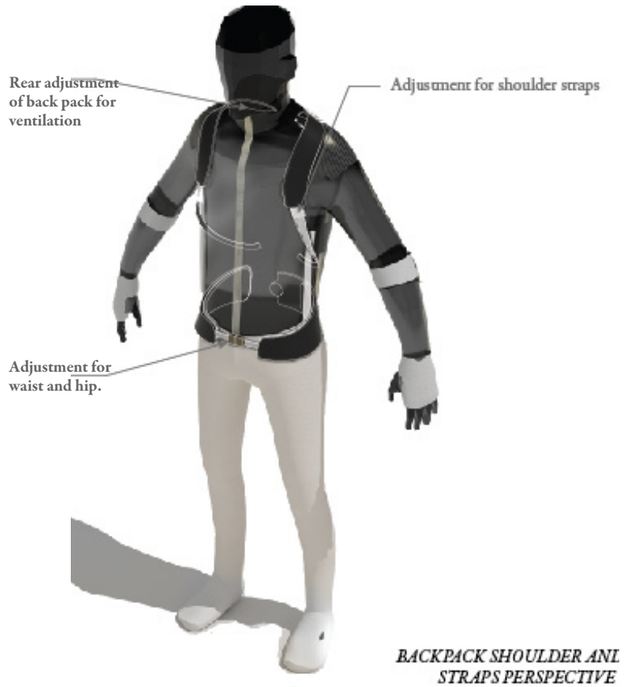
(Centre) Three layer shell garment (2017) **[Fig. 5.31]**



BACKER LAYER GARMEN



THREE LAYER SHELL GARMENT



BACKPACK SHOULDER ANI STRAPS PERSPECTIVE

air vents that allow for body ventilation and perspiration for the armpits.[42] [Fig. 5.31] This three-layer shell garment is constructed of a durable water-repellent fabric layer, a wind-proof and breathable fabric, and a backer layer for comfort. This material is also known for its trademark name- Gore-Tex, a material based on thermo-mechanically expanded polytetrafluoroethylene (PTFE) and other fluoropolymer products. This composite fabric contains pores that are 1/20,000 the size of a water droplet, making it impenetrable to liquid water while allowing water vapour molecules to pass through for ventilation.[43] Depending on the climate, additional insulation can be added such as goose down for colder climates or synthetic insulation for climates with high amounts of moisture.[44] [Fig. 3.58]

PONCHO TARPS

The geometry of the poncho takes the shape of a pentagon. There are individual cells of energy harvesting materials such as p.v. foils, split-ring resonator metamaterial fabrics, piezo-electric harvesting fabrics, thermoelectric harvesting fabrics, and a weather barrier made of ultra-high-molecular-weight polyethylene

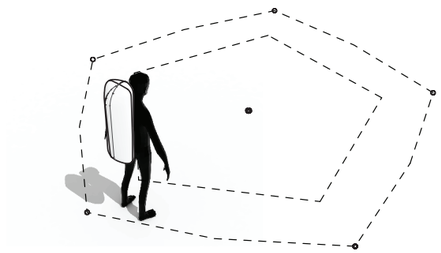
(Left) Energy harvesting poncho tarp (2017) **[Fig. 5.34]**

(Centre) Assembly steps of poncho tarp and tent (2017) **[Fig. 5.35]**

I.

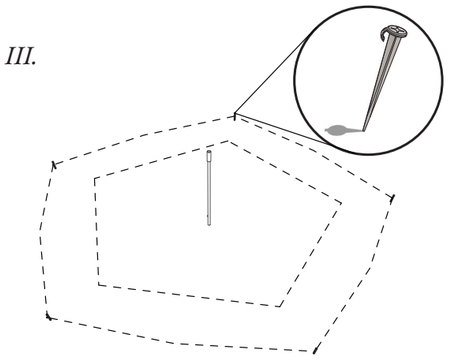
Unload poncho tarp.

II.



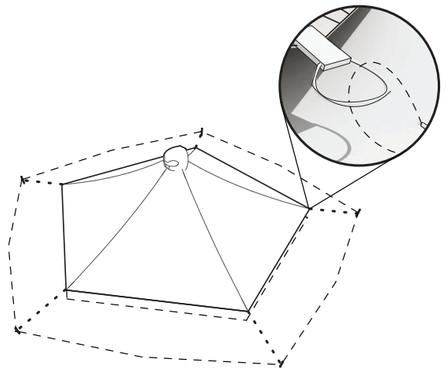
Envision area of use.

III.



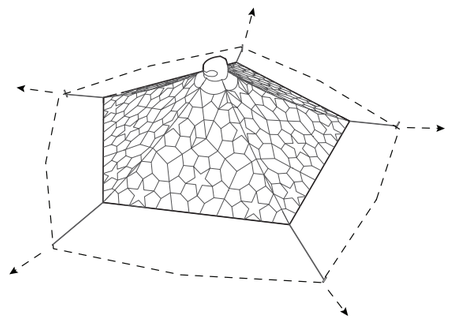
Stakes and main structure set in place.

IV.



Guylines and stakes are stringed through

V.



Tensioned energy harvesting membrane.

[Fig. 5.36] (Above) Boxwall construction with synthetic insulation fill

[Fig. 5.37] (Below) 55L Black Diamond Mercury Backpack, MEC

(UHMWPE). [Fig. 5.26] To accommodate the structurally stable, pentagonal pyramid tent structure, a non-recursive Penrose pattern dictates the cell shapes of energy-harvesting material. A Penrose pattern also acts as a geometric filter that reflects the flows of energies in the surrounding.[45]

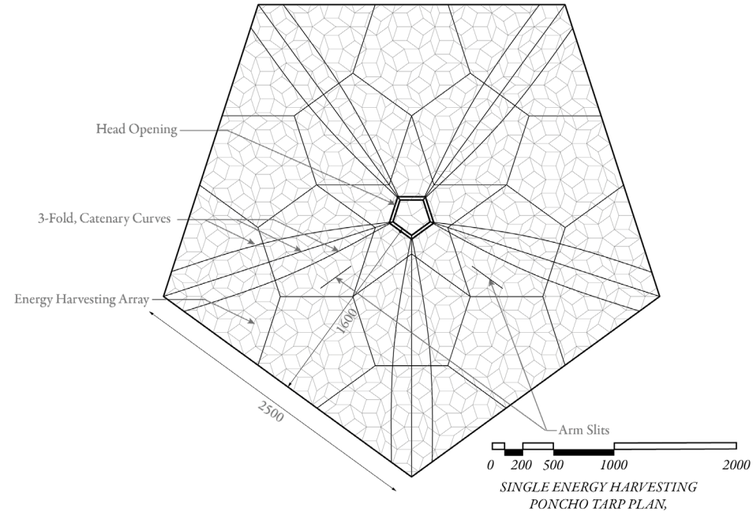
The transformation of the poncho from a flat geometry to a pentagonal pyramid is made possible with five 3-fold seams. These seams are magnetically secured. There are two catenary curves and a straight edge that provides additional structural strength to the edges of the tent structure. [Fig. 5.41]

(Left) 1 : 75 Plan detail tent structures **[Fig. 5.38]**

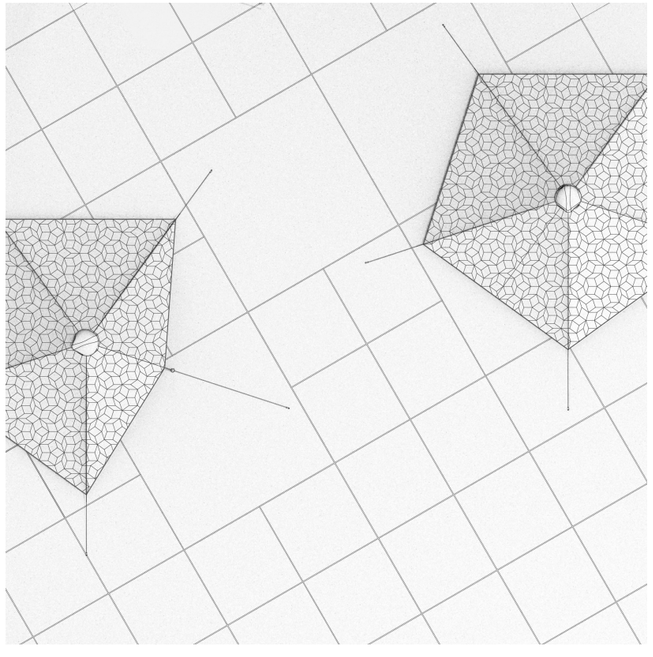
(Centre) Axonometric drawing of poncho tarp structures **[Fig. 5.39]**

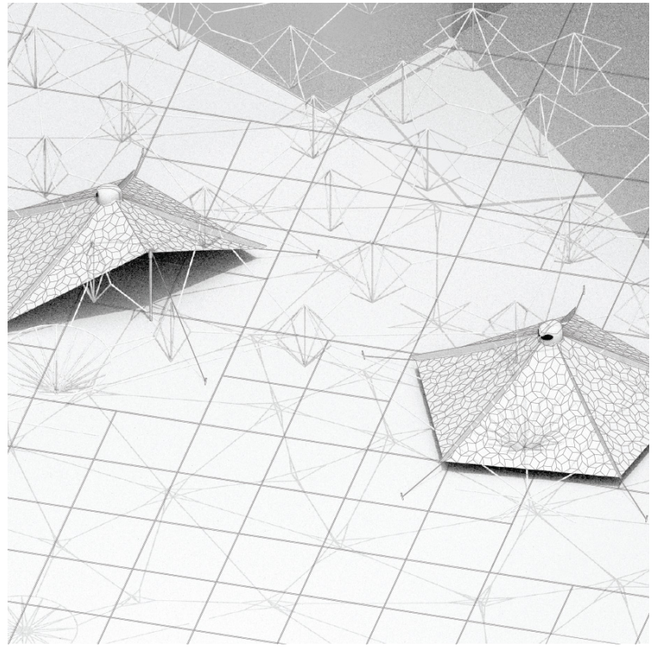
(Bottom right) Axonometric drawing of poncho tarp structures **[Fig. 5.40]**

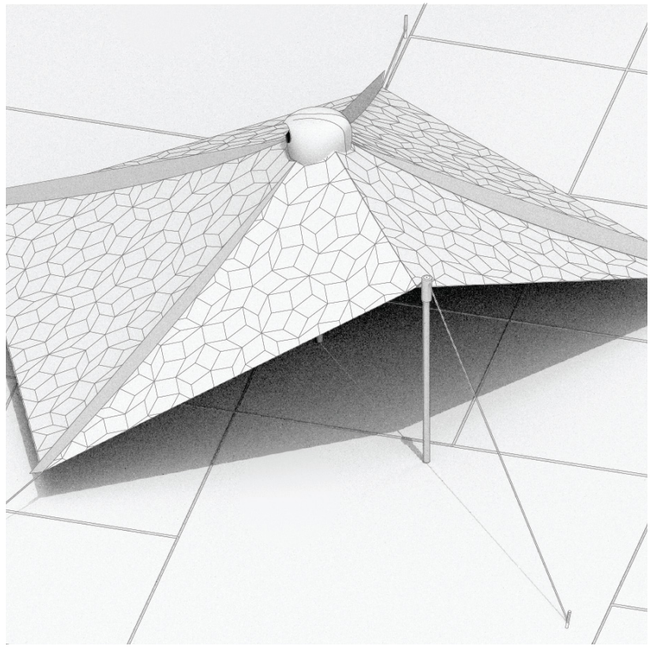
(Facing page top right)Annotated plan drawing of ponch tarp illustrating catenary curve seams and folding points, cell patterning and dimensions **[Fig. 5.41]**

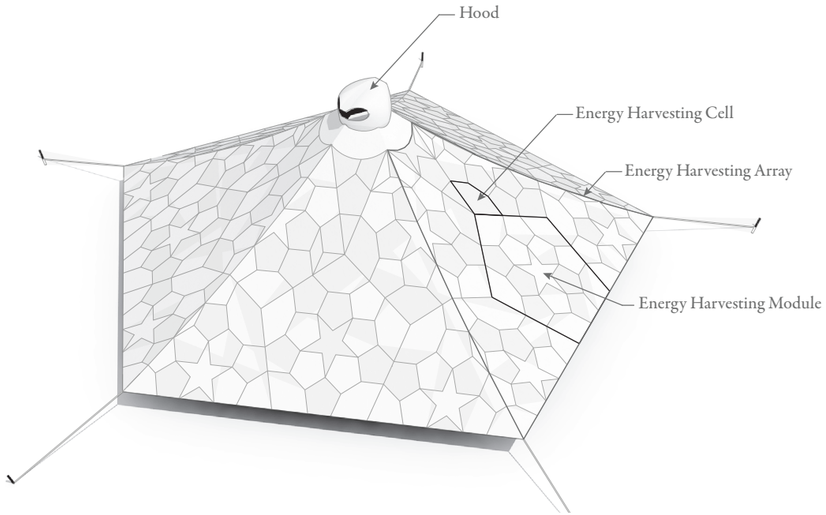


SINGLE ENERGY HARVESTING PONCHO TARP PLAN, SCALE 1:30

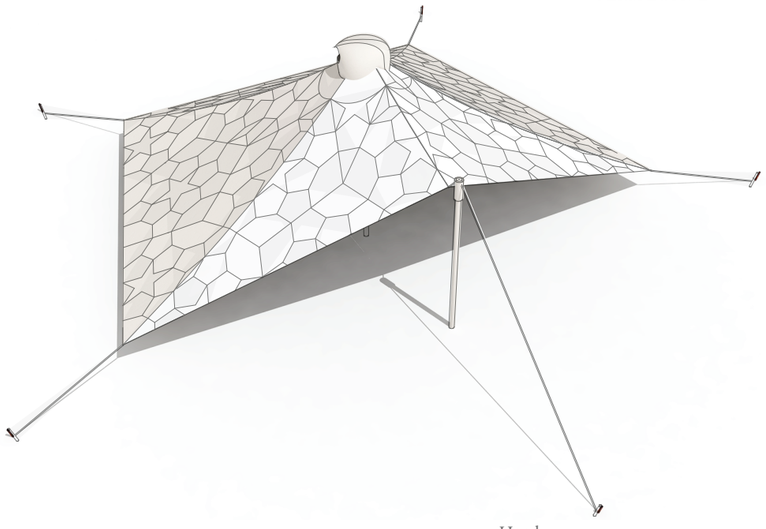


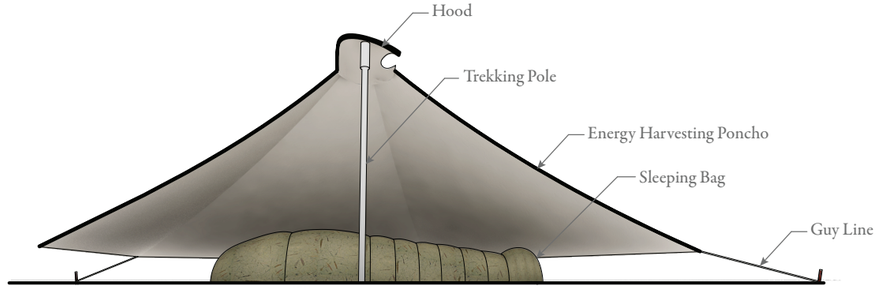




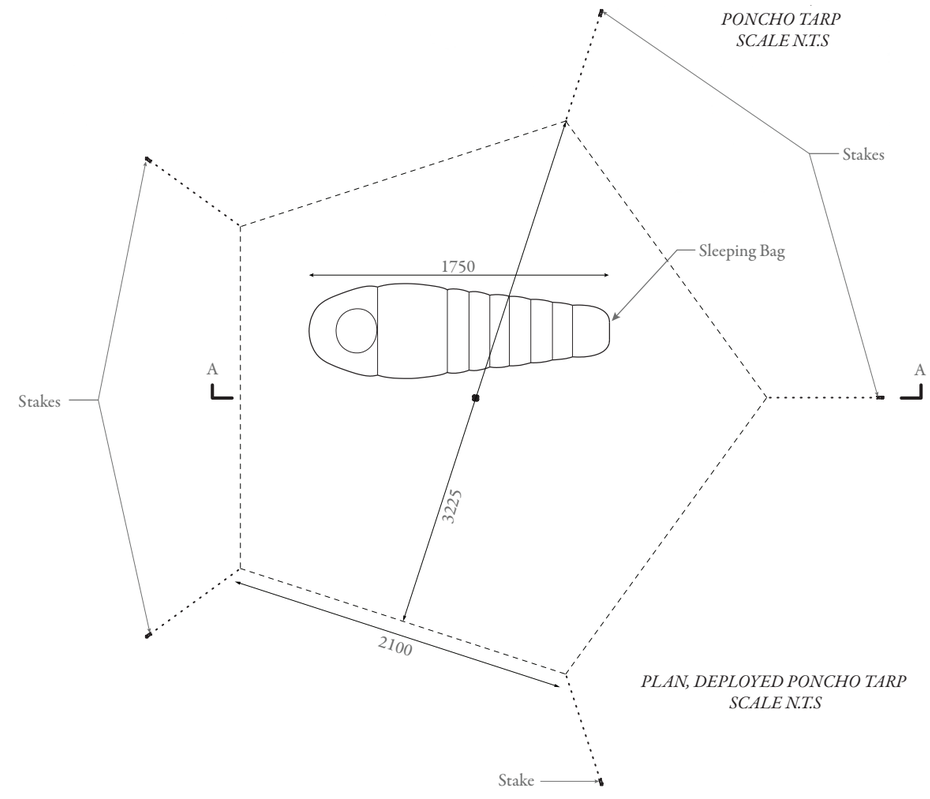


DEPLOYED PONCHO TARP
PERSPECTIVE





PONCHO TARP
SCALE N.T.S



PLAN, DEPLOYED PONCHO TARP
SCALE N.T.S

[Fig. 5.42] **(Facing page) Deployed, opened state of poncho tarp tent set up and poncho tarp section (2017)**

[Fig. 5.43] **(Above) Section perspective and plan of poncho tarp tent set up (2017)**

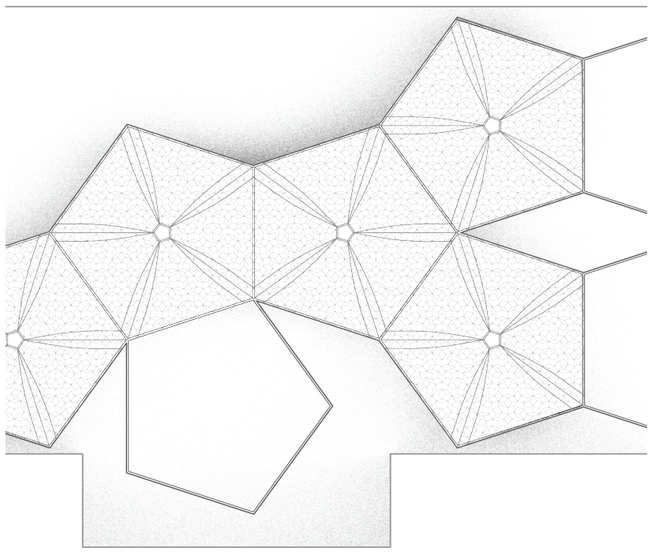
DEPLOYMENT STATIONS

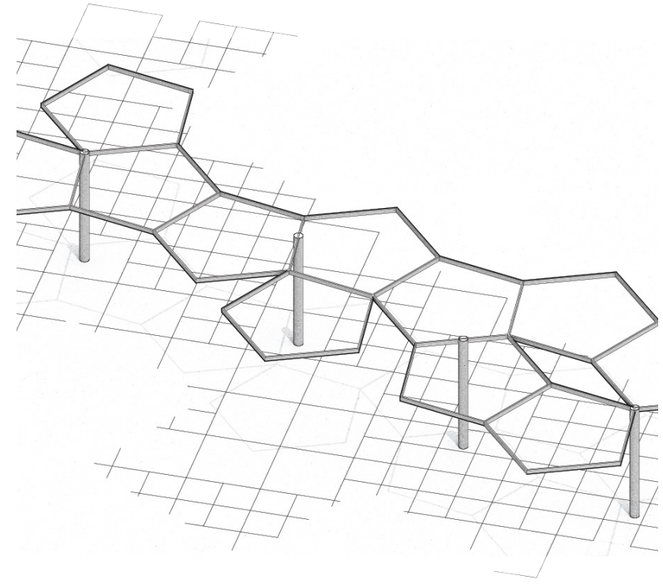
The primary physical structure of the tent consists of two carbon-fiber trekking poles placed at the centre of the tent, along with a trekking pole at the entrance. Ground anchors provide tension for the overall fabrics. Visitors can also hang their ponchos at the deployment stations. These deployment stations provide areas where visitors can collect energy while inhabiting the alleyway. Altogether, 22 deployment stations provide additional shade and gathering areas when visitors utilize their structures. [Refer to plan Fig. 5.47]

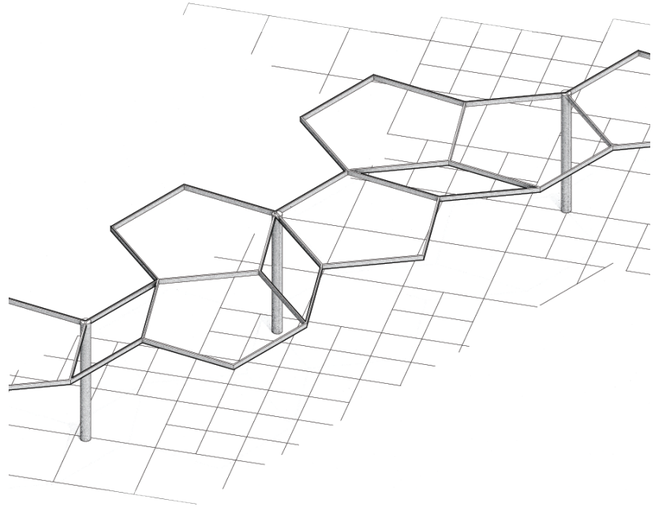
(Left) 1 : 75 Plan detail of deployment stations. Stations are equipped and unequipped with poncho tarps. **[Fig. 5.44]**

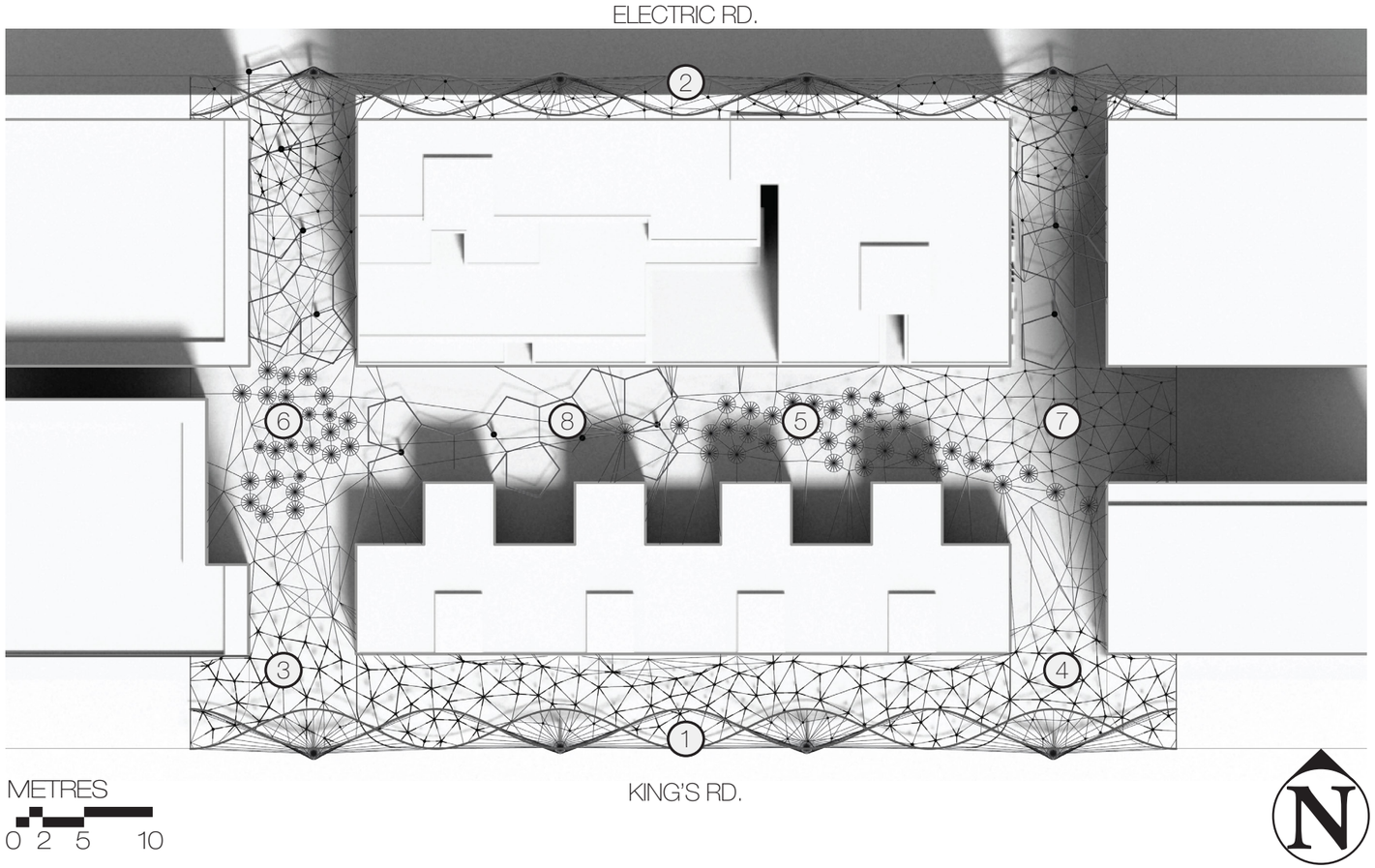
(Facing page top) Axonometric drawing of deployment stations **[Fig. 5.45]**

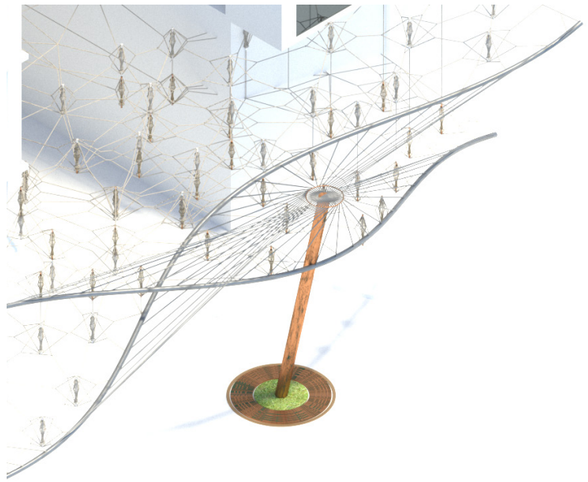
(Facing page bottom) Axonometric drawing of deployment stations **[Fig. 5.46]**











SPATIAL ORGANIZATION

The public space program provides areas for pedestrians to rest, relax and inhabit the alleyway and street scape. The public space consists of overlapping areas with different experiences. These areas are found on the sidewalks that line King's Rd. and Electric Rd. (1)(2), both southern entrances (3)(4) and the western and eastern intersections of the alleyway (6)(9). [Refer to plan Fig. 5.47]

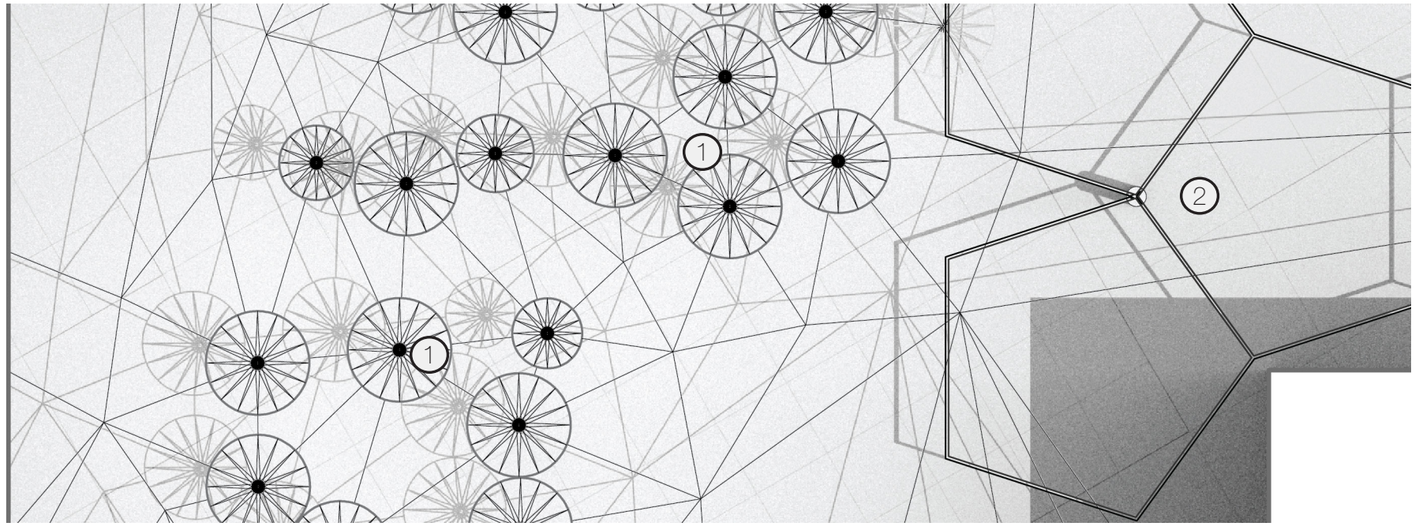
CANOPY SPATIAL EXPERIENCE

The sidewalk spaces are met with a canopy structure overhead and an elevated platform for pedestrian congregation. The canopy structure above has roughly 300 nodes of interacting components that range from 1000 mm to 300 mm in diameter. During the day, these nodes sway slightly in the wind, while during sunset and night emit light in relation to their surroundings. Along the sidewalk is a gentle rhythm

(Above) 1 : 250 Canopy Site Plan **[Fig. 5.47]**

(Facing page) 1 : 75 Plan Detail of Stop and go Area **[Fig. 5.48]**

1 King's Rd. Circulation, Stop and Go Area
2 Electric Rd. Circulation, Stop and Go Area
3 West Poncho Tarp Deployment Station
4 East Poncho Tarp Deployment Station
5 Central Alleyway Poncho Tarp Deployment Station
6 Congregation Area
7 Semi-private Space for Deployed Poncho Tarps
8 Congregation Area



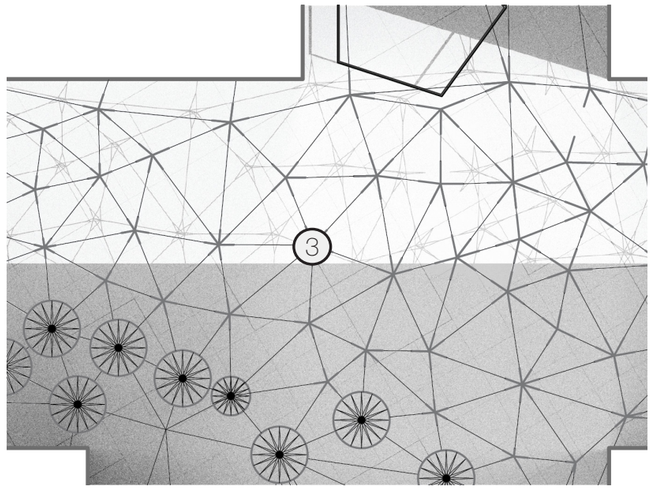
created by a human breathing inspired HSS tube. This HSS tube guides pedestrians along a natural rhythm as they walk alongside the canopy. From afar, a gentle curve draws in visitors. [Fig. 5.51]

In addition to the primary canopy structure are stations in which pedestrians can hang poncho tarps so that solar, heat, kinetic, and radio energies can be collected and stored in batteries. These deployment stations extend from the alleyways and into the streets while also providing additional shading to visitors. The stations also provide pedestrians more mobility and comfort by allowing their poncho tarps to be hung while collecting energy. There are 28 deployment stations in the area.

The eastern intersections of the alleyway are met with hanging nodes that visually connect the canopy structure with the ground surface. These are called elongated nodes and are energy sensitive; they react to the presence of people walking by and emit light based on heat, vibrations, radio waves, and sounds. [Fig. 5.49]

(Above) 1 : 75 Plan Detail of Congregation Area **[Fig. 5.49]**

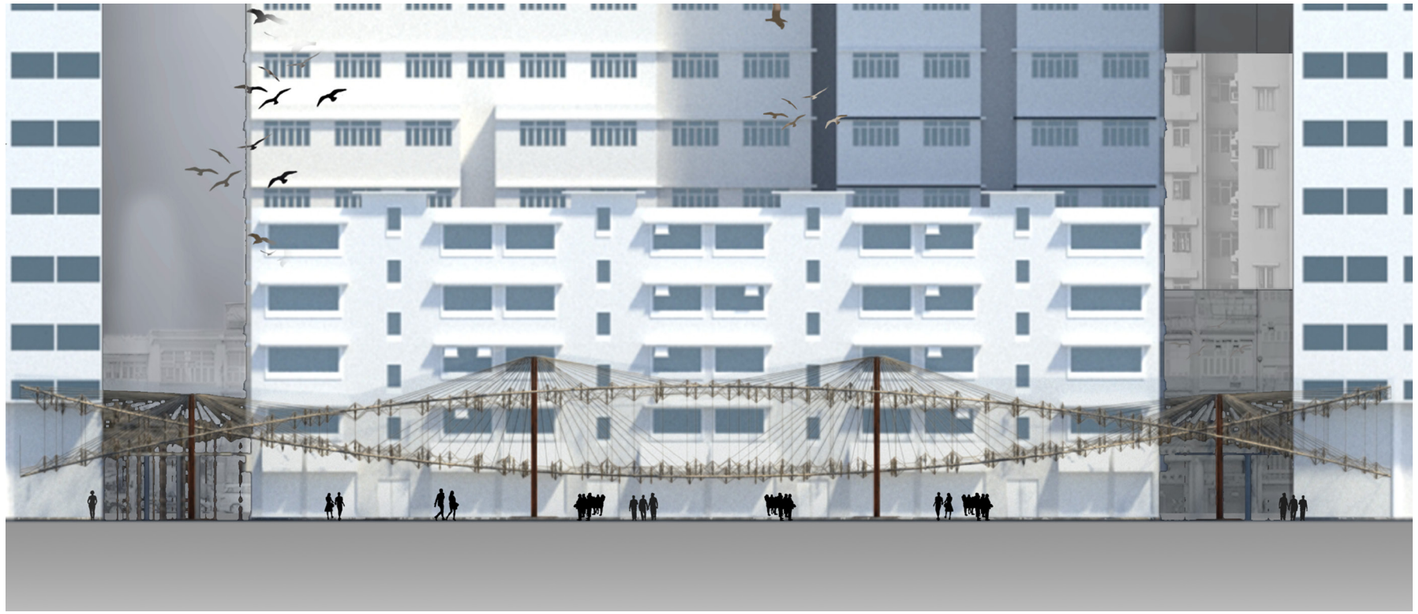
(Facing page) 1 : 75 Plan detail of semi-private space for deployed poncho tarps **[Fig. 5.50]**



1 Elongated Nodes

2 Poncho Tarp Deployment Stations

3 Canopy Nodes



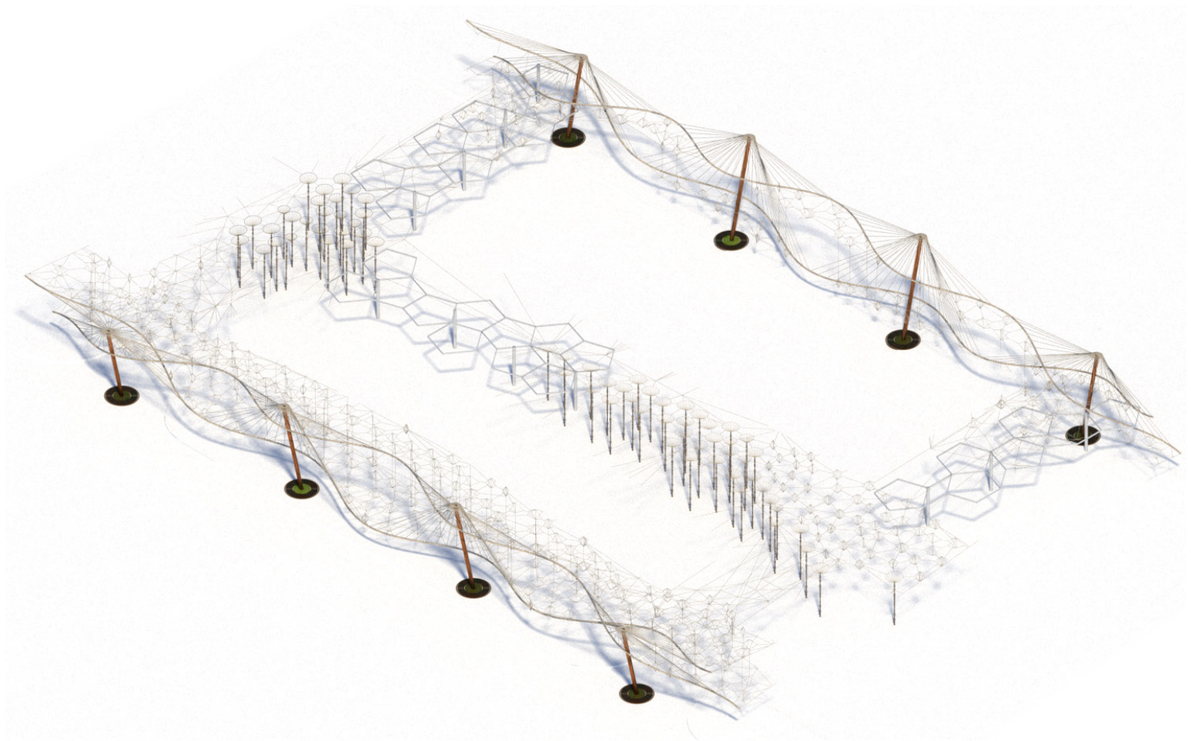
The western intersection is semi-private space. Pedestrians can set up their poncho tents and stay for prolonged periods of times. Overhead, smaller nodes sway and provide a dynamic environment. They glow and pulse during the night while visitors inhabit the alleyways. [Fig. 5.57]

(Above) 1 : 200 Longitudenal elevation **[Fig. 5.51]**

(Facing page) 1 : 400 Site elevation **[Fig. 5.52]**

[Fig. 5.53] 1 : 75 Section of canopy

[Fig. 5.54] 1:50 Section of canopy



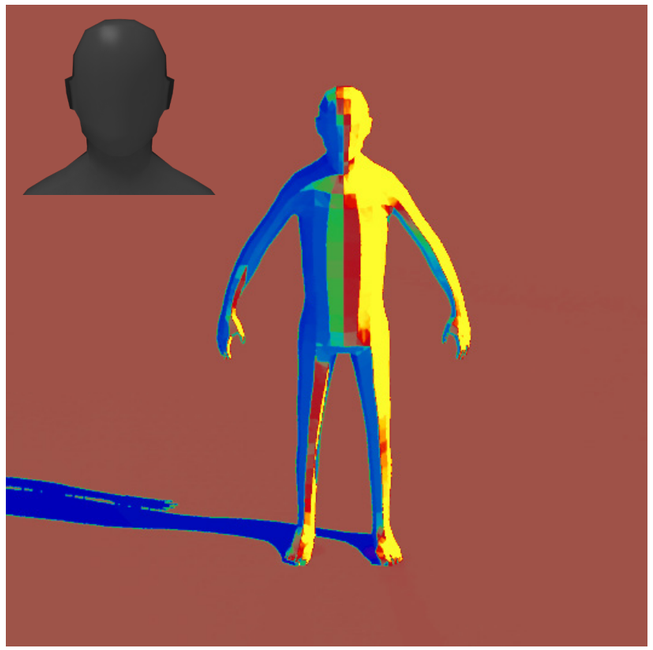
[Fig. 5.55] **(Facing page) Axonometric view of area of study**

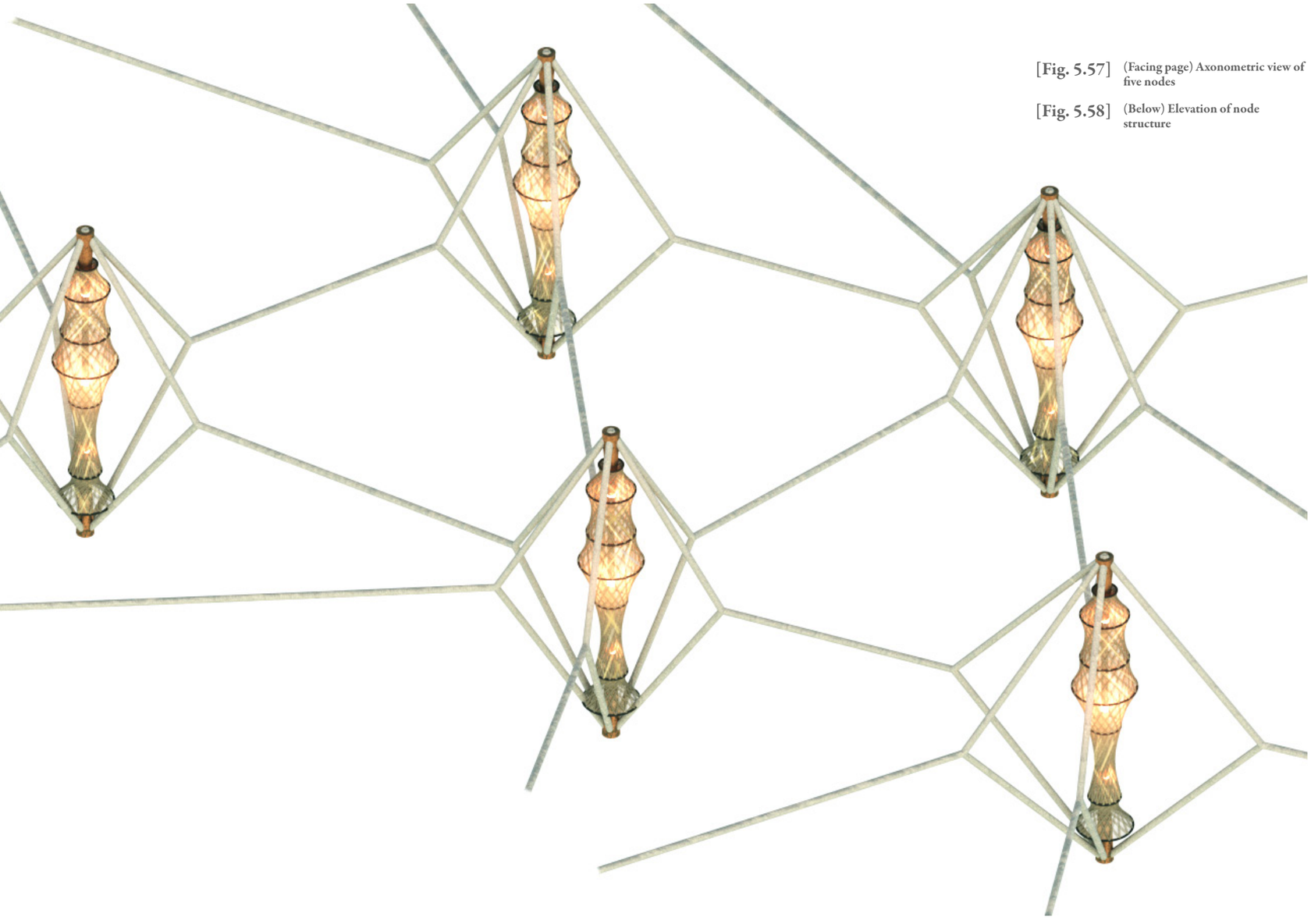
[Fig. 5.56] **(Below) Irradiance map of the human body and elevation of human head**

A MOMENT IN THE SUN

A solar exposure study was conducted on an average human body on March 21st, the first day of spring at 9am. This study was done to capture a moment in which the sun rises over the city's apartment towers and spreads its rays onto the streets of the North Point Lowlands. A stepped gradient of irradiance values registers on the study model. The solar exposure value then corresponds to the intensity of heat perception. There were two studies that influence the components of the canopy structure, a solar exposure study on the head and another on the torso. These two studies produce nodes and elongated nodes that are the geometrical translations of the different intensities of heat perception at the head and body respectively. [Fig. 5.56]

Nodes are part of the canopy structure and are in constant tension with their surroundings. Each node holds a bamboo shoot at the centre, which acts as





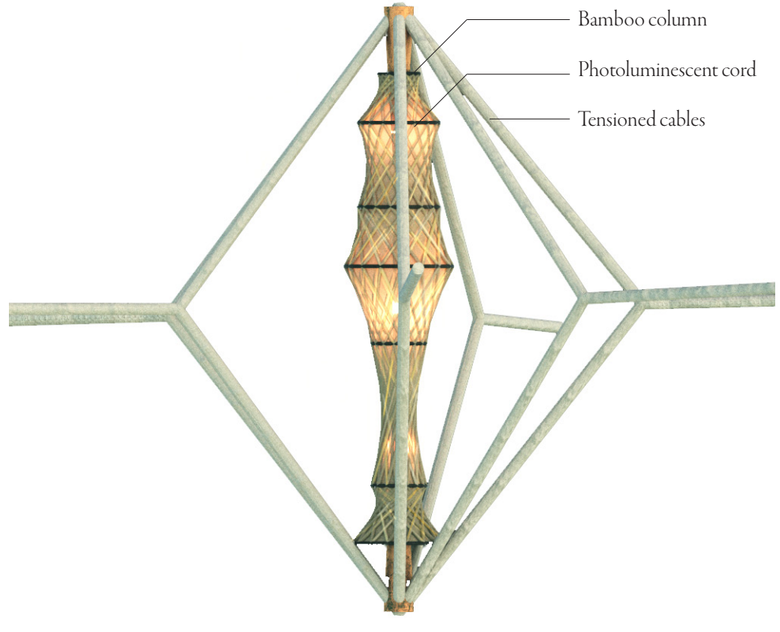
[Fig. 5.57] (Facing page) Axonometric view of five nodes

[Fig. 5.58] (Below) Elevation of node structure

a compressional member. Each bamboo member is encased by seven rings with diameters that correspond to solar exposure values. Nodes correspond to solar exposure values at the head, such that higher values increase the occurrence of large diameter rings of the node, and low values correspond to smaller diameter rings.

NODES

Node rings are braided together with reflective cords with metallic beads housed within them. The braid pattern is constructed by having 24 cords perpendicular to each ring that are then rotated 4 spaces in both directions. This braid pattern creates the effect of a surface geometry that reflects light and glows according to the surroundings. Within the center of the rings is the bamboo member with energy-harvesting materials that power the lighting system of each node. [Fig. 5.57] [Fig. 5.58]

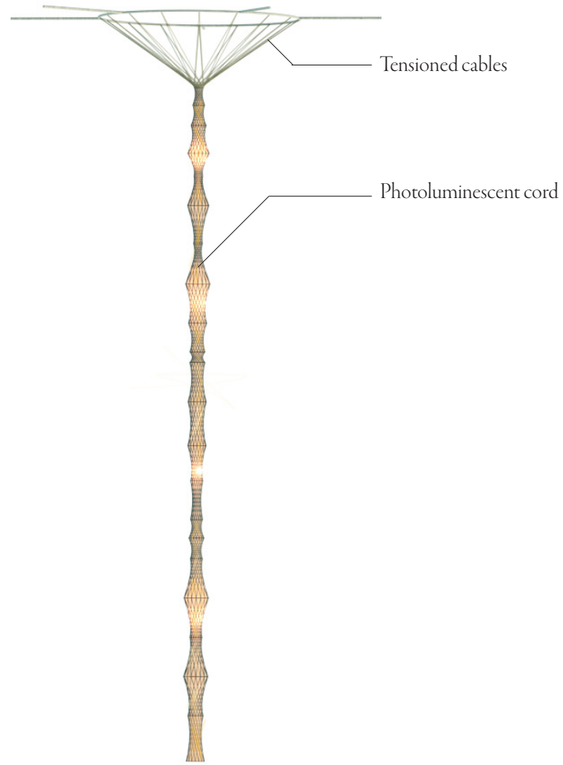


[Fig. 5.59] **(Facing page) Axonometric view of six elongated nodes**

[Fig. 5.60] **(Below) Elevation of elongated node structure**

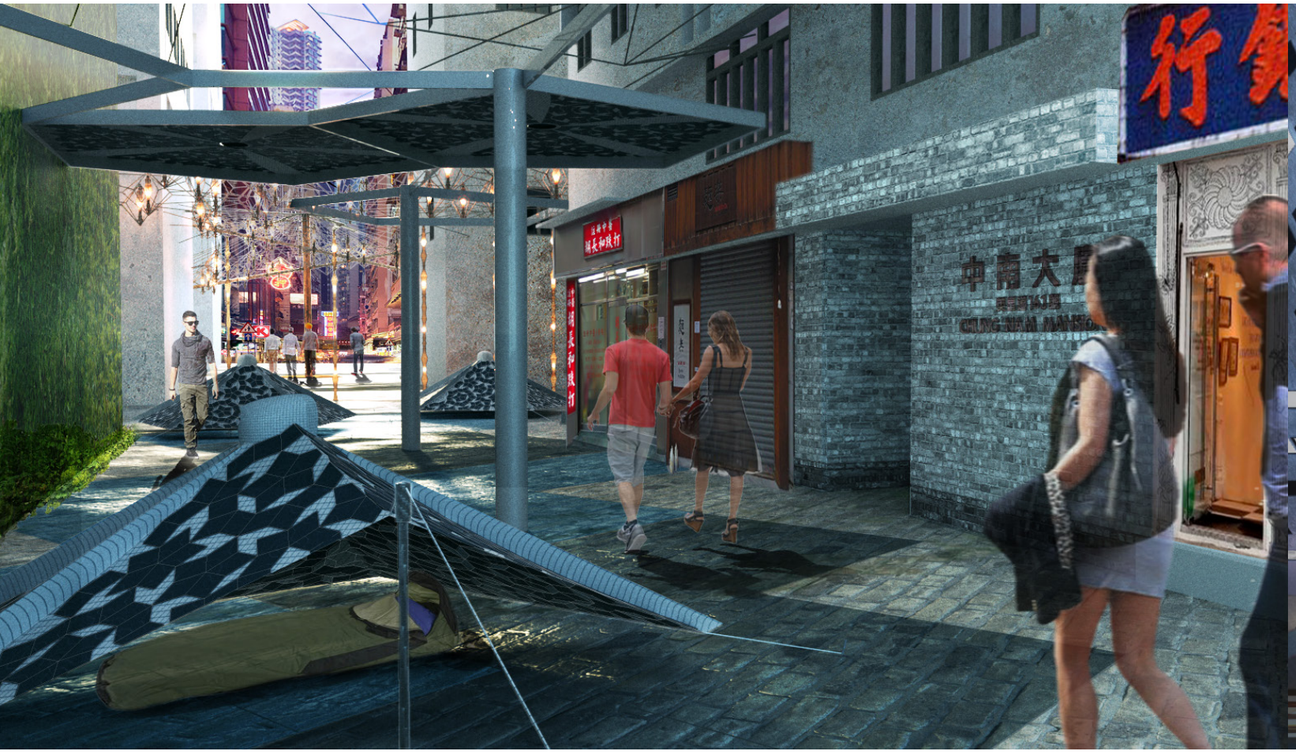
ELONGATED NODES

Elongated nodes are also part of the canopy structure and are in constant tension with their surroundings. Each elongated node consists of 22 rings that are braided together with solar optic cords with LEDs and suspended in tension. Elongated nodes correspond to solar exposure values at the body, such that higher values increase the occurrence of large diameter rings, and low values correspond to smaller diameter rings. These elongated nodes are reflections of bodily perceptions of heat at 9am on the first day of spring. [Fig. 5.59] [Fig. 5.60]

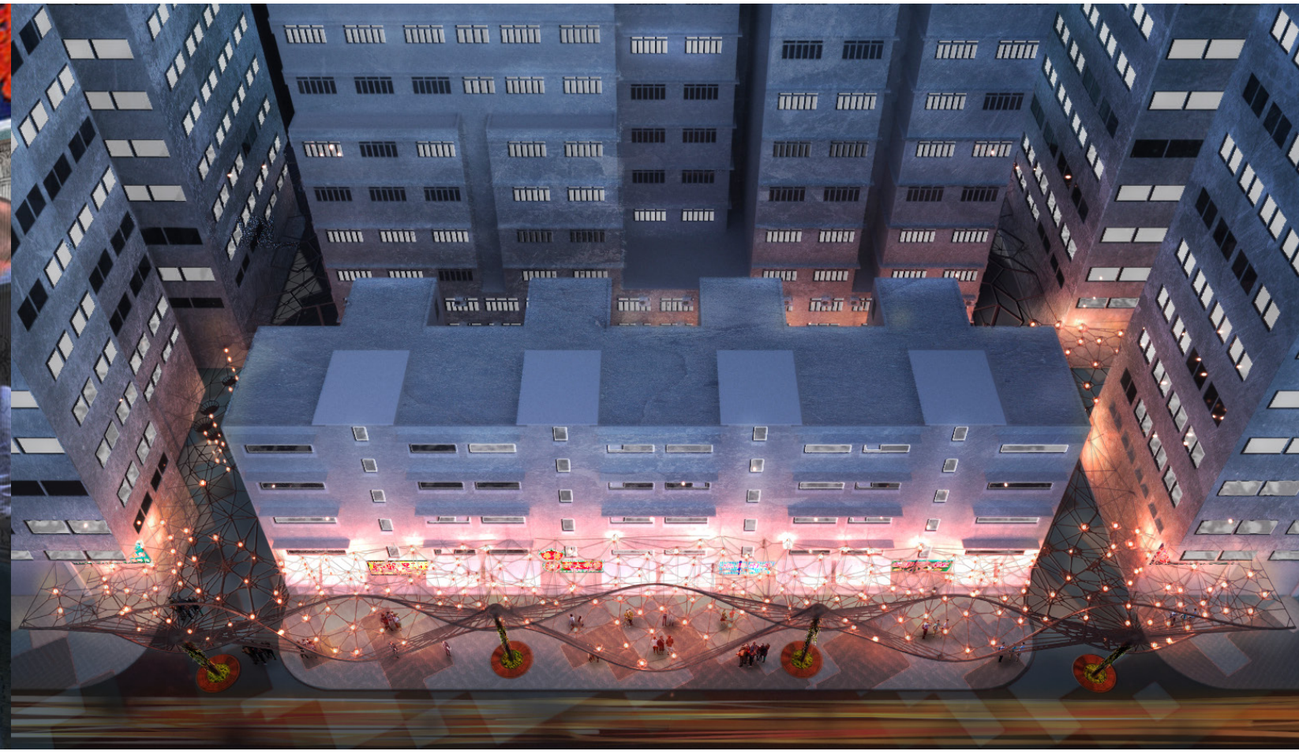


[Fig. 5.61] Alleyway rendering during at dawn

[Fig. 5.62] Street rendering along Electric Rd. at dusk



[Fig. 5.63] Alleyway rendering of deployment stations and poncho tarp structure at dusk



[Fig. 5.64] Aerial view of canopy and subject at night

[Fig. 5.65] Street rendering from afar along Electric Rd. at dusk

[Fig. 5.66] Street rendering from afar along King's Rd. on a rainy night

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34. Ibid. Figure 4-1
35. Ibid. Figure 4-1, See piezoelectric materials.
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43. See Tools & Techniques, Clothing Skurka, Andrew. The Ultimate Hiker's Gear Guide, Second Edition: Tools and Techniques to Hit the Trail. Washington, DC: National Geographic Partners, 2017.
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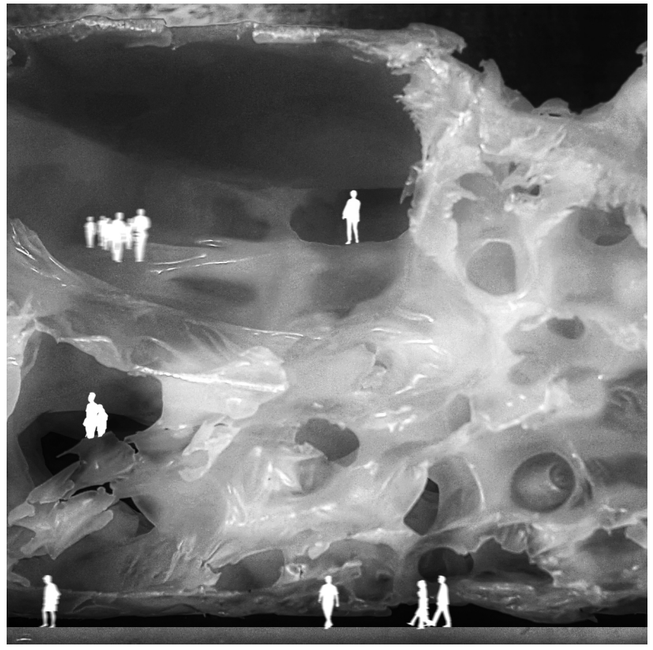
06 CONCLUSION

Today, architects and designers can iteratively create living, hyper context-sensitive, built-environments.[1] Without a doubt, natural living systems prevail as a guide. This thesis presents a new capability for addressing extremely complex design issues by adhering to research regarding living systems and questioning their constituents. To address this theoretical question and discourse, there are multiple trajectories in design that encompass it. To reiterate, one trajectory refers to the demiurge[2]; the alchemic architect that liberates the attributes of the material world with spatial syntax in relation to the human body, its sensibilities, and nature.[3] Another trajectory lies at the confluence of architecture and certain disciplines in the sciences such as physics,[4,5] chemistry,[6] and biology.[7] Research indicates that forces like electromagnetism show influence over our surroundings and, in turn, shape our associations with them.[8,9] Furthermore, there are materials with designed chemical compositions that yield self-active properties, low embodied energy, and attributes of energy generation.[10] Biological influences reveal subtle and hidden phenomena that can be interwoven to co-generate space. These trajectories aid in advancing physical living architectural systems. Another trajectory is rooted in the socio-political cyborg[11] [Fig. 6.1] and its manifestations in technology and the digital paradigm in architectural space-making.[12,13] Equally as potent in design is the power of science-

[Fig. 6.1] (Left) Human, Cyborg: Human-computer/ artist/ writer/ shaman/ scientist by Lynn Randolph (1989)

[Fig. 6.2] (Right) Wax and Water diagrammatic model, Programmed Matter (2016), by Author



fiction story-telling about cyborgs and the intertwining of human inventions and natural systems to create thought-provoking aesthetics about the built environment of the future.[14,15,16,17] These approaches in design address issues of sustainability and complex socio-political relationships to co-generate physical form and expression. Most importantly, the thesis speaks of a meta-narrative about a deeply inclusive design process that responds to hardships in a world of calamity.

LIVING ARCHITECTURE SYSTEMS GROUP

A key influence on research for the thesis is the work of the Living Architecture Systems Group (LASG) and, specifically, the Scaffolds stream led by Philip Beesley. The Scaffolds stream researches and designs architectural test environments that approach natural living systems. For instance, the previous project of Philip Beesley Architects, the Sentient Chamber (2015), has allowed Colin Ellard, the Human Experience stream leader at LASG, to observe a set of architectural relationships that influence cognitive, psychological, and physiological conditions of the human body.[18] The work allows for the study of observable changes to one's psyche, body, and immediate surroundings, so that the project produces studies relevant to the Human Experience stream at LASG.[19] This collaboration strengthens the

relationship between the built environment and its living occupants to approach near-living environments.[20] LASG's objectives are to integrate light-weight and flexible components and develop them into physical envelope prototypes. This charged theoretical and experimental discourse allows this thesis to envision the possibilities and influences on the built environment of tomorrow.

BRUSHSTROKE COMPOSITIONS

Moving forward, the thesis takes the possibilities afforded with architectural test environments by incorporating physical phenomena and physiological experience. In particular, the practice of generating formal compositions of artwork from experiencing physical phenomena lies with brushstroke compositions. The practice reveals the experience of meta-physical phenomena to generate a fluid, graceful, strong, and dynamic transferral of meaning: energy.[21,22,23] The act of conveyance in calligraphy, seen in Henry Ho's circular brush strokes, embodies an expressive quality and structural importance of written black-and-white spatial compositions.[24] The thesis design utilizes meditative qualities gained from the practice of calligraphy to influence a structural composition that conveys vital energies. Understanding how electromagnetic forces govern our world[25] and influence how bodies are

(Left) 百會 - "bǎi huì" (many connections) & 湧泉 - "yǒng quán" (gushing spring). Running script in black ink by author. 百 means hundred or a very many. 會 means to understand, to gather. 湧 means gush forth, rise or well up. 泉 means spring or fountain.

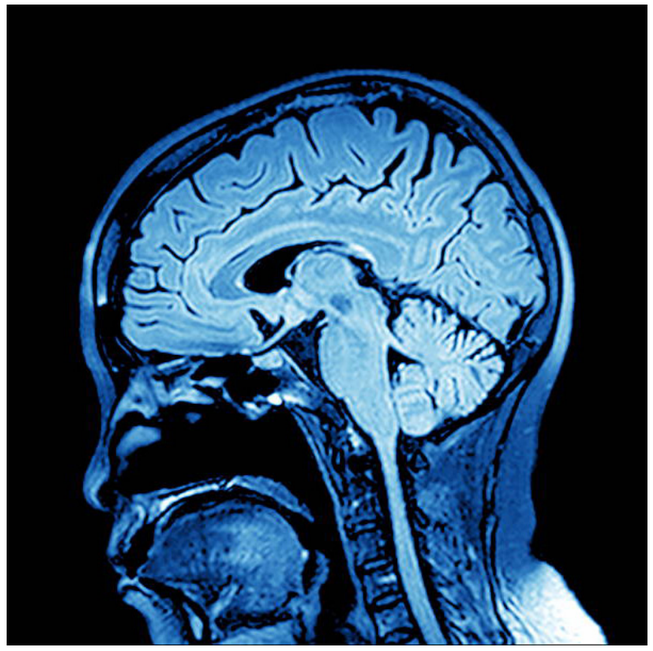
[Fig. 6.3]

[Fig. 6.4] **(Right) New ways of observing the world, a typical computed tomography scan of the human head**

inherently shaped by surroundings allows for the pursuit of a resonating architectural composition. It is evident that this type of architectural design transitions from qualities of firmitas to where the architectural surface is embodied with seemingly invisible and felt energies from new types of surfaces, structures, and materials.

INTERDISCIPLINARITY AND SUSTAINABILITY

In addition to the works previously mentioned, works by Jenny Sabin Studio, LabStudio, and Paz Gutierrez's B.I.O.M.S allow for a cluster of sustainable design concepts, pertinent in natural living systems, to be readily sought out and studied as a guide for a new architectural test-environment. Each example consists of different materials, modes of production, and design tools. Furthermore, these architectural test-environments encounter complex ecological networks that inform the construction of their physical structures. There are complex networks of information, energy, living beings, and matter inextricably influenced by interdisciplinary design processes. By proposing another form of emergent and bottom-up architecture, with the inclusions of ecological living networks made visible by the interdisciplinary research mentioned above, this thesis encounters the seemingly unknown phenomena learned with an approach to interdisciplinarity in architecture. Specific



concepts examed earlier in the precedent study section (page 54 - 59) reveal material concepts applicable to sustainable design such as self-organizaing materials, adaptability and regeneration in building materials, recyclability and biodegradability in building materials, are pursuits to be explored in the near future.

CYBORGS

This thesis is concerned with complex socio-political relationships, which is a central theme when speaking about cyborgs. This is applicable to the thesis outcome, as a detailed understanding of natural and urban environments can enhance relationships between dweller, nature, and surroundings. Thus, research regarding cyborgs and their influence in the design of architecture enhances the human agency of inhabitants. It does so by finding new connections between dweller, nature, and surroundings, so that new structural, spatial, programmatic, and material strategies can be developed. The result is an architecture that fosters a hyper-individualized dwelling to allow for more meaningful modes of living in a designed environment.

SCIENCE FICTIONAL STORY-TELLING

Science fictional story-telling is a powerful tool used to inform this thesis.

(Left) Powered exoskeleton race, Cybathlon (2016), ETH Zurich/ Allessandro Della Bella **[Fig. 6.5]**

[Fig. 6.6] **(Right) Section of proposed canopy structure**

Timothy Morton articulates that the apocalypse is a notion that carries potential for bringing change to the neglect of the Earth.[26] The film precedents have provided examples where dystopic scenarios are visually conveyed through film. These are also apocalyptic scenarios that present an abstracted image of the world aimed towards a path to confront our reality.[27] As a result, the apocalypse refers to a consciousness of the urban ecology, allowing the thesis and its design proposal to inspire its structural form and expressions accordingly.

THE DESIGN

The design proposal in the North Point Lowlands of Hong Kong presents a co-generated public space with physiological perceptions of site energy. The main guiding site influences for the design are the various qualities of spring-time, and the flow of heat throughout the day. These bodily perceptions of space are used to generate a relationship between inhabitant and structure. Other site influences include the perception of electromagnetic forces throughout the site by translating these attractions and repulsions into patterns, radiuses, orientations, and directions of shapes, lines, and masses. The act of perceiving these forces is embodied and expressed in a sculptural form. Furthermore, breathing, a physiological function, injects life into line and structure, so that life can be embodied in architecture.

Materials are arranged in tension with thin, lightweight cords that support a canopy, which catches and releases the latent heat and electromagnetic forces of the site. This formation of a new type of architectural membrane gives way to a surface that brings to light a perceivable combination of self and surroundings that approaches an unrestrained form of being.

DESIGN TRAJECTORY

It is evident that from transcending the notion of firmitas, architecture is no longer seen as divisive but inclusive through embodied energies and blurred psycho-social perceptual boundaries. One can project the research in this thesis into different types of injections to surfaces and also methods of sustainable design in the built environment. Different types of feeling and magnifications of the self can become surfaces that generate new spaces to be inhabited and made comfortable. Much of the design processes and ideologies presented here are generative, meaning that they are formed from the bottom up, and enable multiple feelings and living constituents to form. The behaviours of living matter will continue to act as a mode of designing. The most crucial deliverable of the research is that the interdisciplinarity and knowledge offered by other kinds of expertise enables a reformed definition of what architecture is. Biological, textile, fashion, sport, meditative, electrical, theoretical physics, and engineering disciplines are potent with views and ideas of how the world functions. These collaborations allow for design to become much more enabling, rather than simply exist as a complete and unified idea for the inhabitation of space.

ENDOTES

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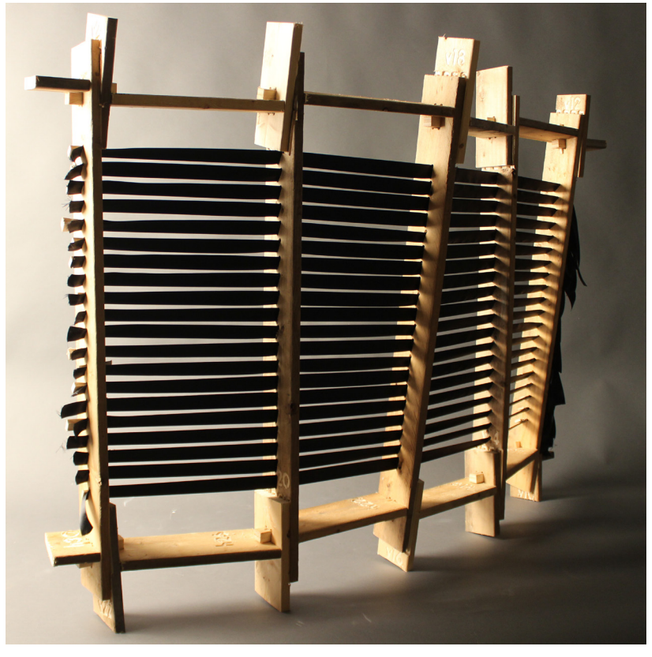
07 APPENDIX

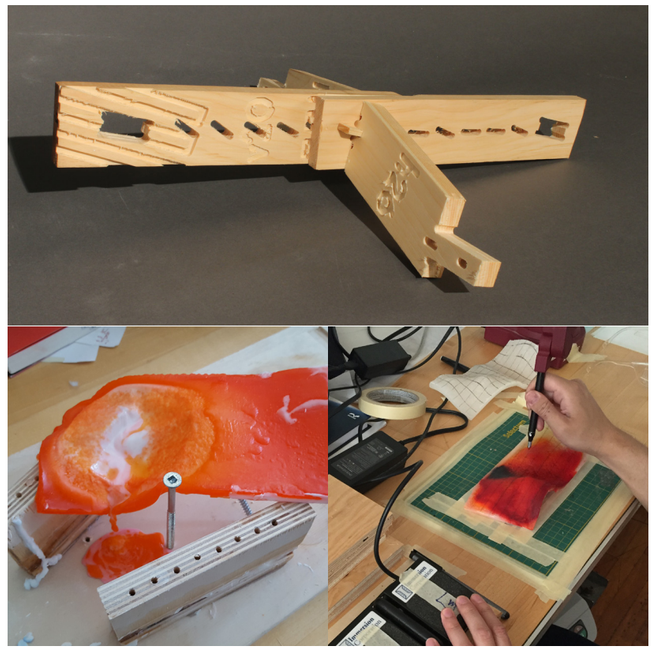
The following pages contain unconventional design explorations that feature generative processes. This design methodology consists of simple components that synthesize into complex ones for use in the construction of the built environment. Like the bottom-up design processes for textiles explored in Jenny Sabin Studio's Lumen, the following factors are used to construct complex material surfaces, some influenced by science fiction: low embodied energies as a design guide, material behaviours that influence form, biodegradable fabrics, elastic membranes, solar cells, weather barriers, shape memory alloys and spines that influence air flow. As with previous material in the thesis, the explorations use nature as a guide in design, so that designers and architects can control and tweak variable parameters that influence its form, purpose, and, ultimately, its contextual application. This offers great opportunities for architects and designers to exercise change and influence over the built environment regarding such issues as sustainability and suitability. Thus, these material explorations are in pursuit of what architecture can be by approaching a tuned synchronicity with their greater surrounding environments at unforeseen scales and influences. Projects, research, and speculations comprise the following pages that approach these aspirations.



[Fig. 7.1] **(Left) Wall exploration with varying influences over light**

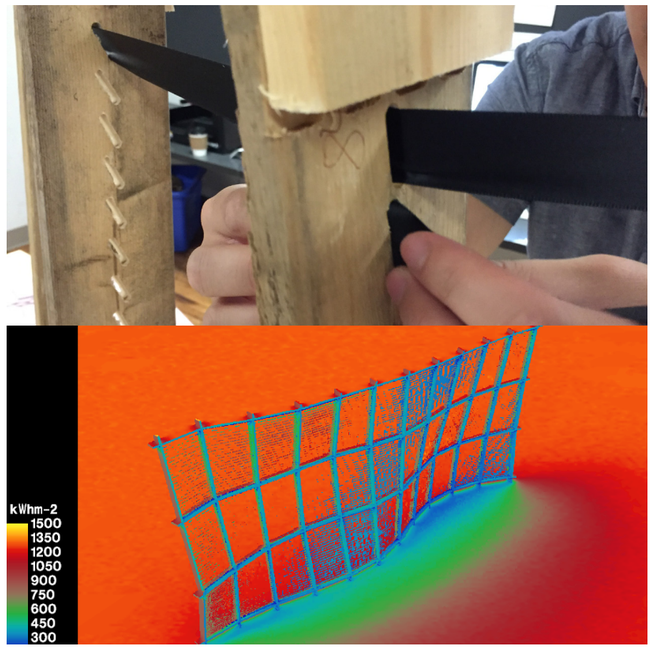
[Fig. 7.2] **(Centre top) Interlocking joints for demonstration, (Centre left) Paraffin wax form finding, (Centre right) Digitizing, wax to isocurves**

[Fig. 7.3] **(Right top) Tensioned ribbons accompanying tuned interlocking joinery, (Right bottom) Thermal/ solar analysis**



COMPLEX JOINERY AND FORM FINDING

This project is a complex, biodegradable wall, designed and constructed in conjunction with Scott Proudfoot. [Fig. 7.1] It is a design exploration into digital fabrication methods that follow design principles inspired by nature. The exploration is influenced two-fold by nature: firstly, by implementing low embodied energy principles in its building life cycle; secondly, by allowing self-organizing and adaptability principles to influence its function and form. To reduce material waste, wood joinery techniques were employed to remove adhesives and fasteners. Additionally, a three-axis CNC cutter was used to generate controllable interlocking joinery of its structural framework through optimized digital modelling and direct tool path export. The form of the wall is informed by different mixtures and colours of paraffin wax. This material was chosen because its fluid features can be controlled. The properties of wax act as a guide to inform bending and opacity, organizational form features of wax that can be transposed onto surfaces. Solidified mixtures and colours of paraffin wax are heated with a hot lamp, and its final form is digitized into isocurves for use in Rhino. [Fig.. 7.2] The last step involves a tensioned ribbon strung through slots in its framework so that the paraffin wax, by way of its colour and mixtures, influences the structure's integrity, patterning and opacity. A light and heat study was completed to optimize and corelate the paraffin wax with structural form. [Fig. 7.3] The final wall is a complex surface that has little waste in its construction and can be disassembled and put together easily. Its and form models the behaviours of more playful natural materials.

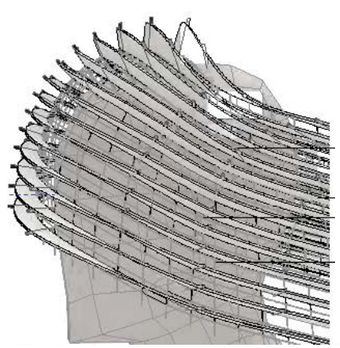


A PROGRAMMED RIBBON

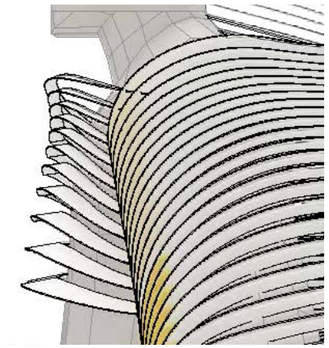
This project embodies a conceptual building material with embedded functions that generate extraordinary capabilities. The project was inspired by Junya Ishigami's Tables for a Restaurant, which featured a pre-stressed steel table that is elegantly thin. [Fig. 7.4] The table was exposed to applied and calculated loads while covered with food and other dining hardware to ensure structural stability. Embedded structural forces were applied to the table creating a deceivingly simple arrangement of aluminum, allowing for seemingly super structural strength.

The following project is inspired by the simplicity of the table which makes its function possible. The material could self-actively exert tension, twist, bend, pull, collect solar energy, and move surrounding air around it. [Fig. 7.5] The material could also have multiple functions so that it is adaptable in many situations. This material is would be coupled to the human body allowing for thermal exchange between body and surrounding environment. [Fig. 7.6] The expanded skin would also have flagellar-like spines protruding from the fins to constantly move and maintain air flow around the body. Tiny and foreign air particulates around the perimeter would interact with the material encasing the body. All together, the garment would provide an enhanced and more accommodating atmosphere for the wearer by conditioning inactive muscles and providing information and communication capabilities. [Fig. 7.7] Further drawings speculate on the potential of a garment being a wearble building.

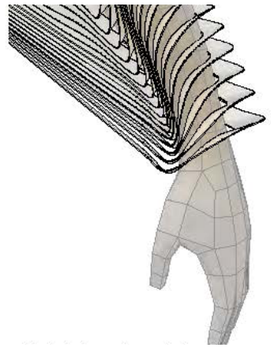
[Fig. 7.4] Junya Ishigami's "Magic Table" Exhibition, Tokyo, Japan. 2005

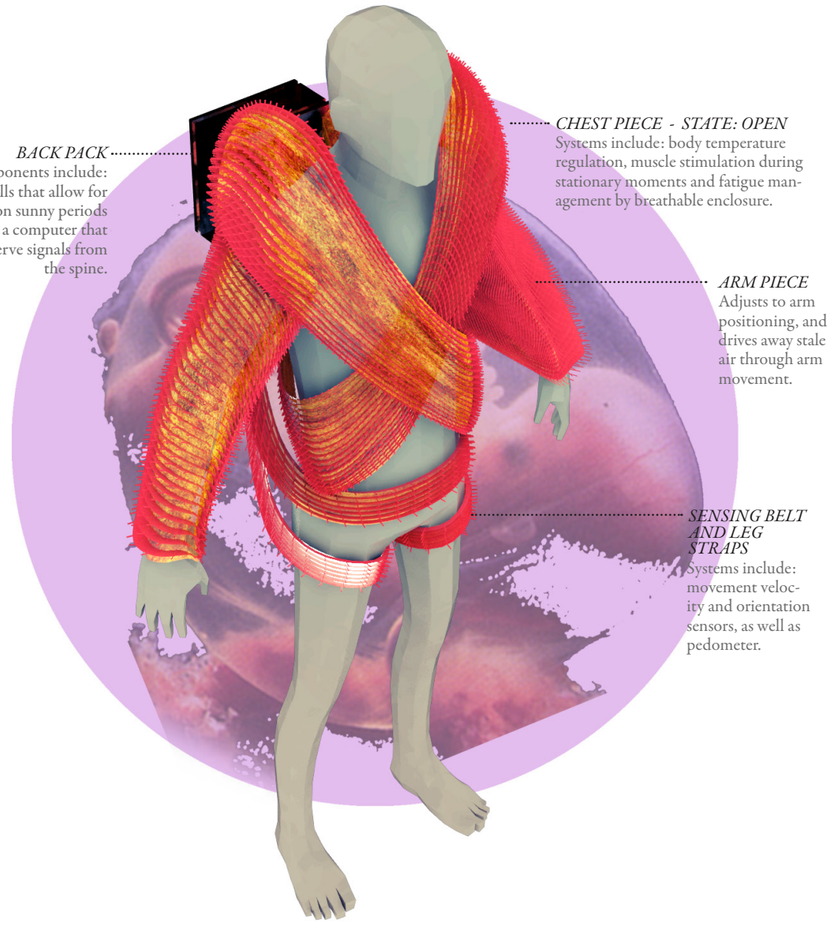


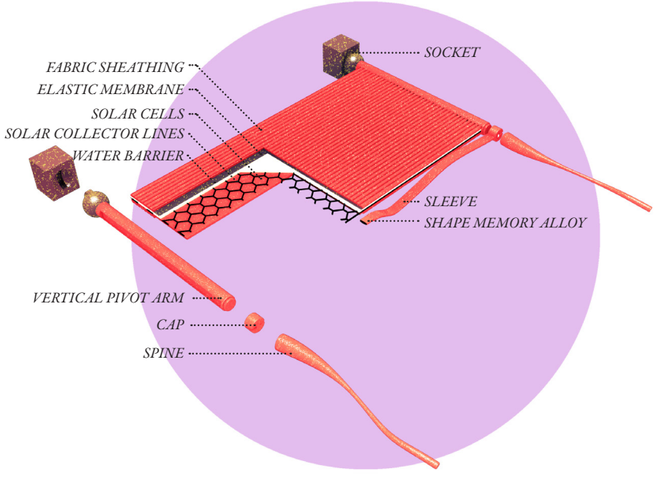
[Fig. 7.5] (Left) Exploded fin detail and flagella detail



[Fig. 7.6] (Centre) Fin-Suit with back pack, chest piece, arm piece, sensing belt and leg straps

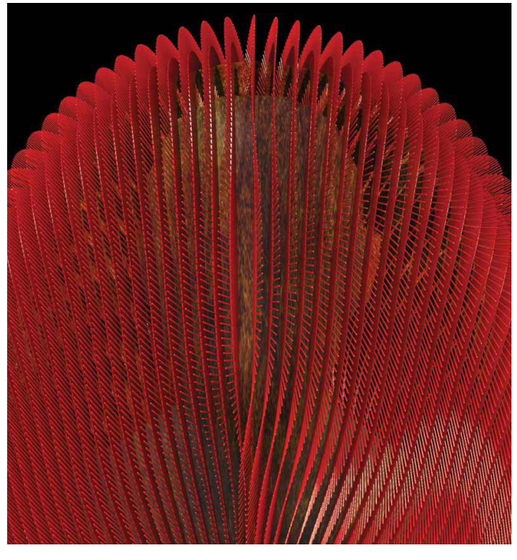


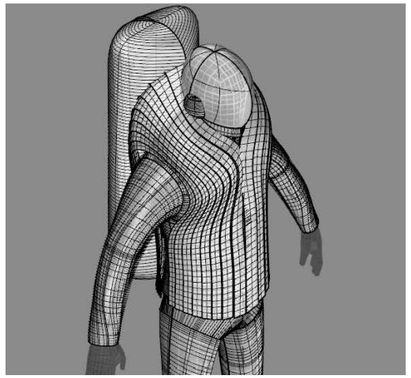




[Fig. 7.7] (Above) Left to right, Head shell with light and sensors. Shoulder detail, provides heat for muscular conditioning while stationary. Hand detail, flex- suit adjusting to hand positioning.

[Fig. 7.8] (Below) The Flex-Suit provides an enhanced, more accomodating and productive atmosphere to the body. IT coupled the body directly to a building. Temperature is capable of being regulated to condition inactive muscles, body parts an to increase blood flow. Information communication devices are synced and navigated by touch and movement to enhance work place activity and communication.

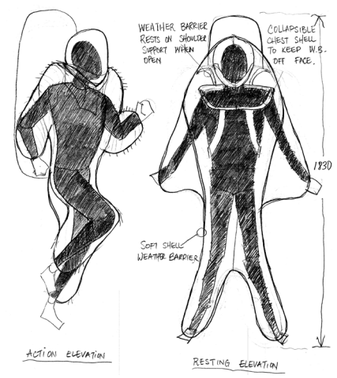


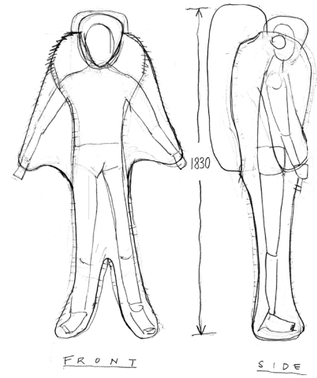


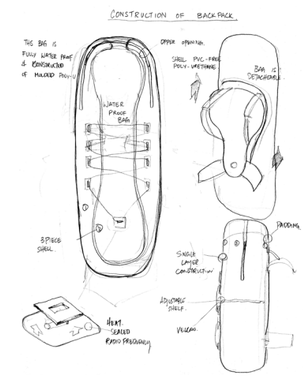
(Top left) Weather barrier, protection from elements like sun, rain, radiation [Fig. 7.9]

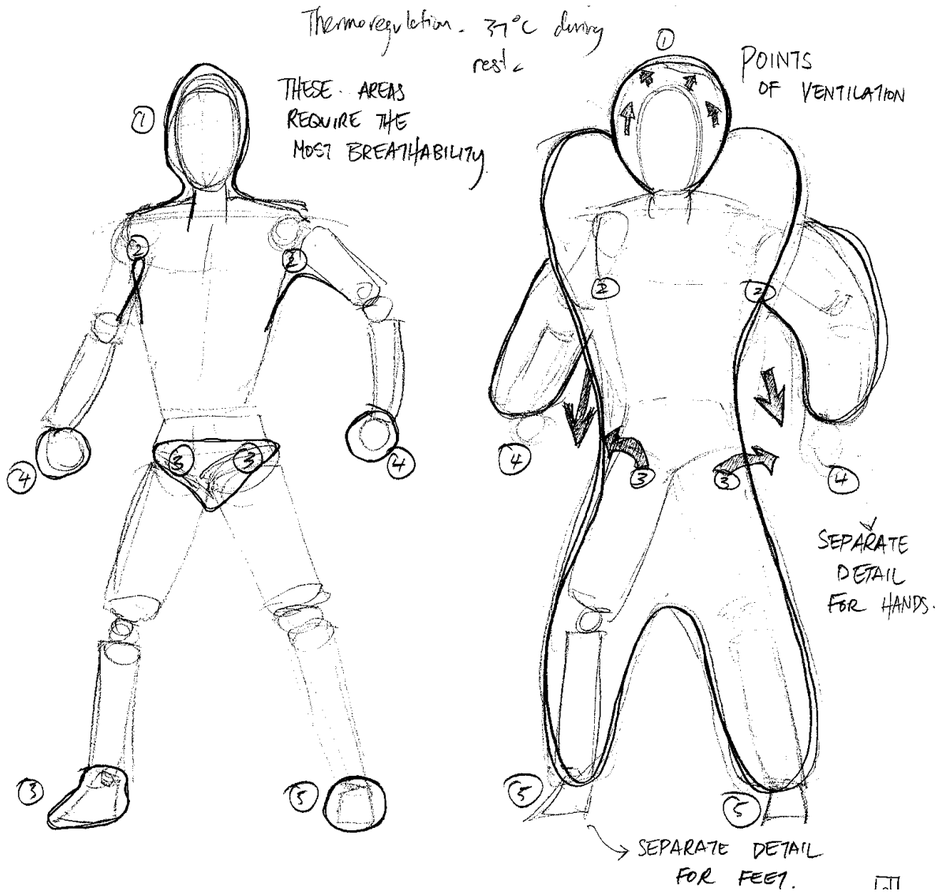
(Bottom left) Neck ports of the cyborg [Fig. 7.10]

(Centre) Thermal readings and reactions. Areas on the body that lose heat for the regulation of the body's internal temperature correspond to the amount of blood flow to the body part. These areas are, the head, groin, armpits and extremities such as fingers and toes.[1] [Fig. 7.11]



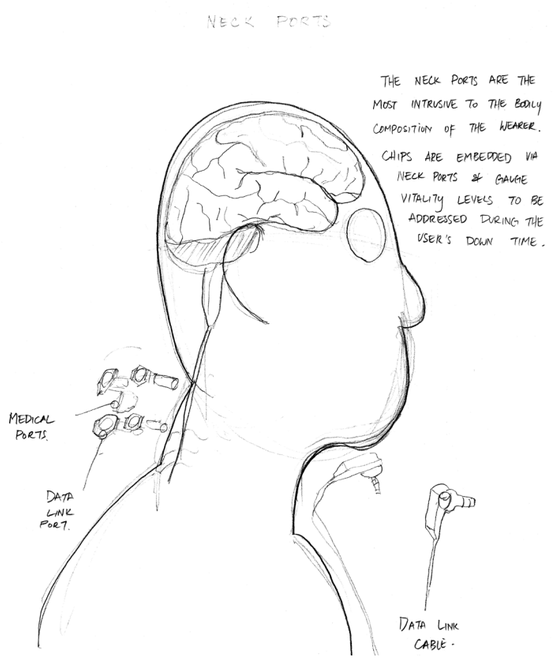


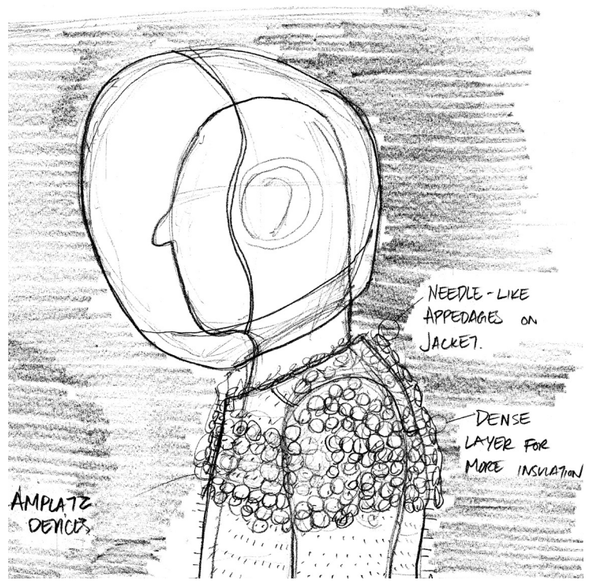




[Fig. 7.12] (Above) Left to right, elevations of the environment mediator suit (EMS) and construction of back pack

[Fig. 7.13] (Below) Jacket detail with integrated Amplatz devices that regulate air flow around body

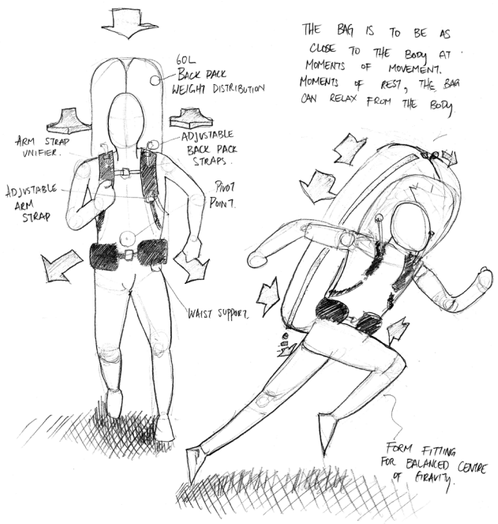


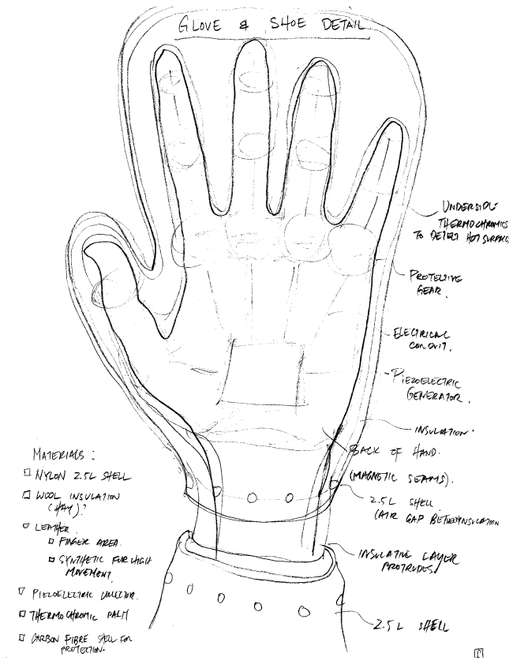


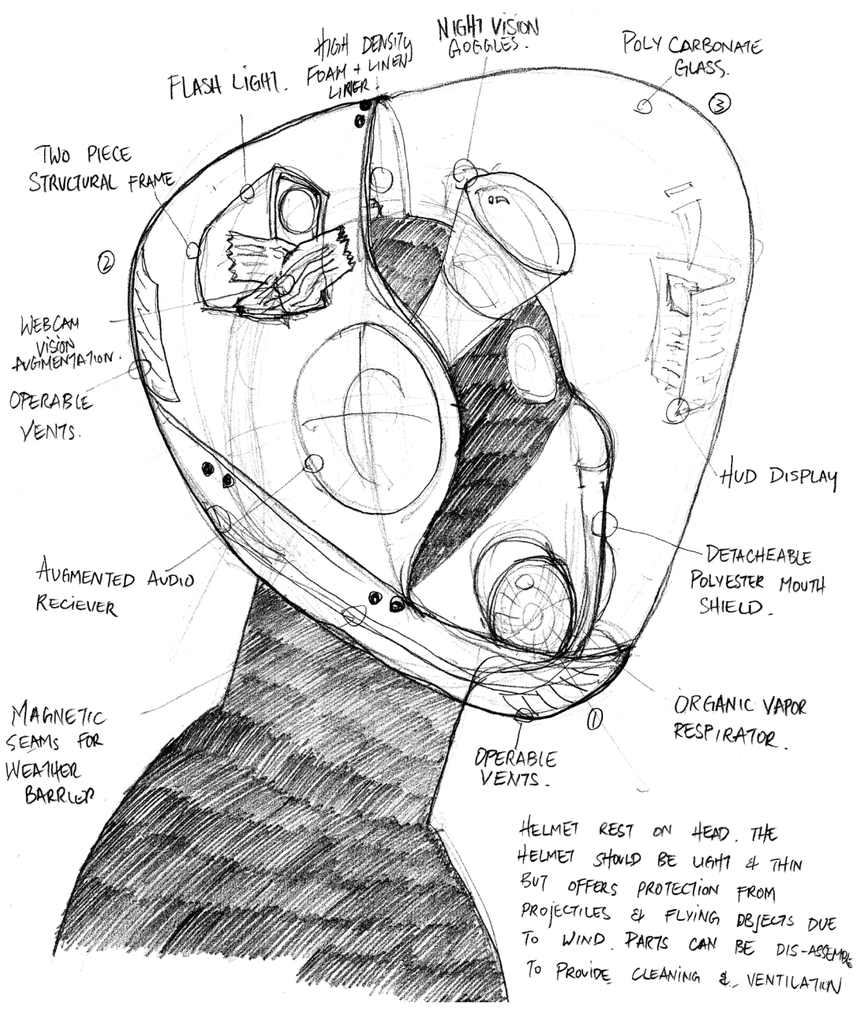
(Top left) Structural loading [Fig. 7.14]

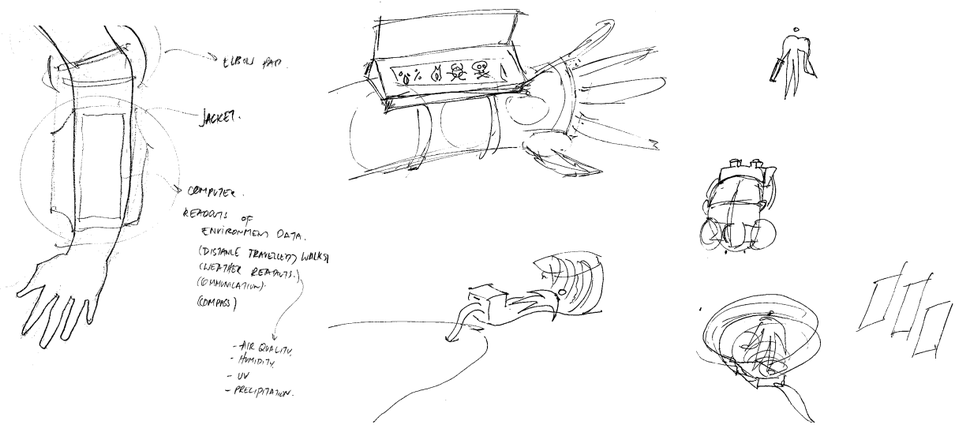
(Bottom left) Glove detail [Fig. 7.15]

(Centre) Annotated helmet parts, [Fig. 7.16]



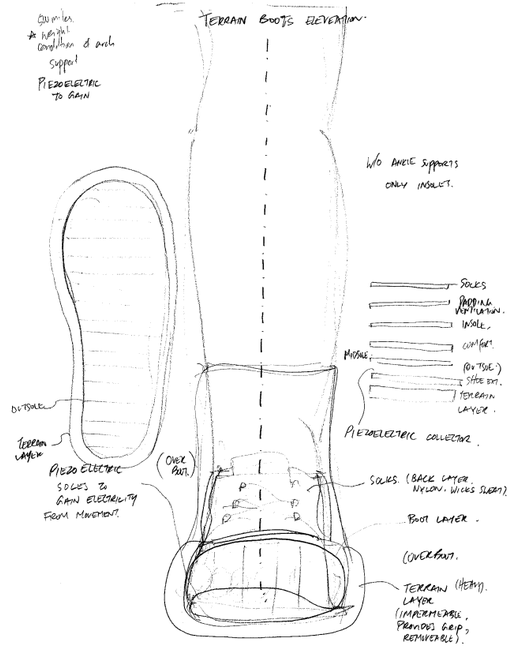






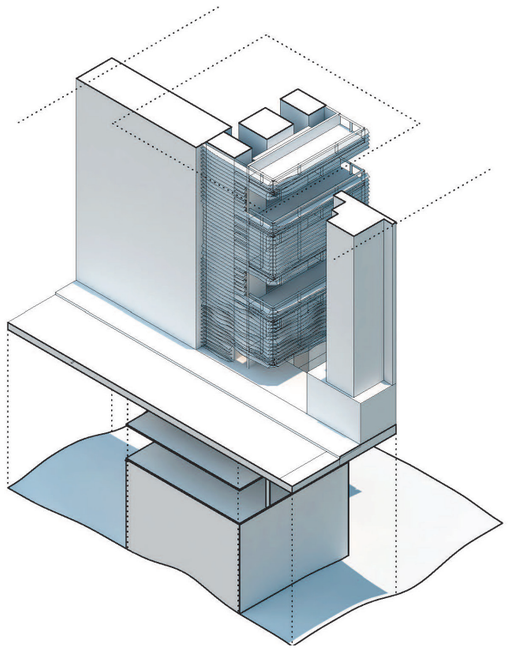
[Fig. 7.17] (Above) Personal device on arm and function

[Fig. 7.18] (Below) Terrain boots elevation



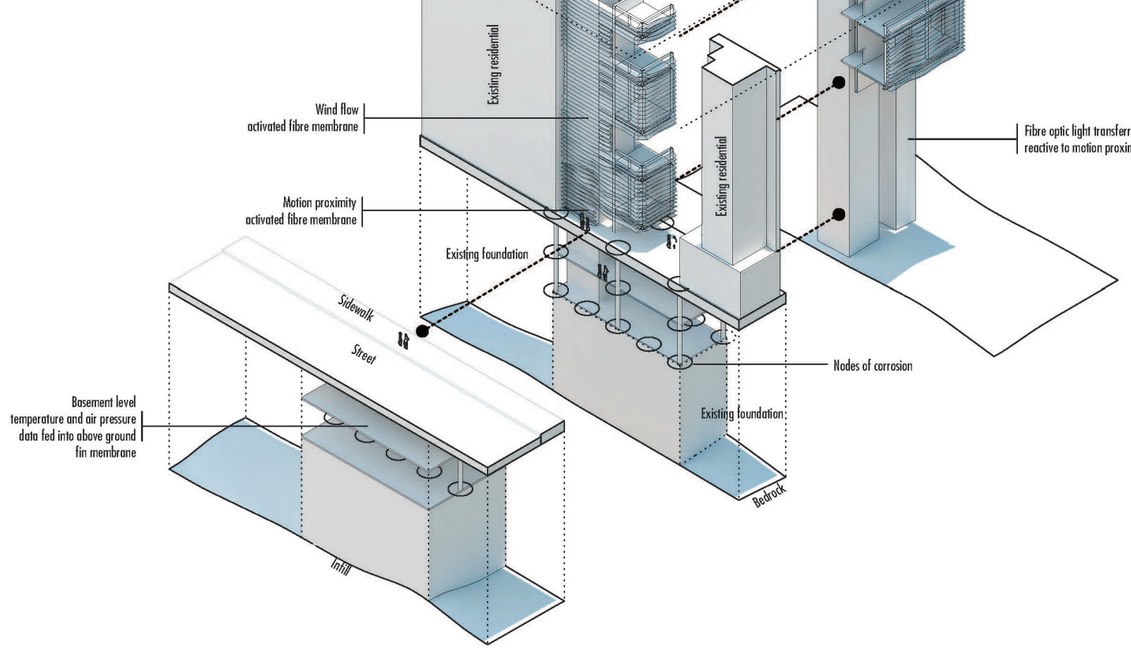
AN ALLEYWAY INTERVENTION

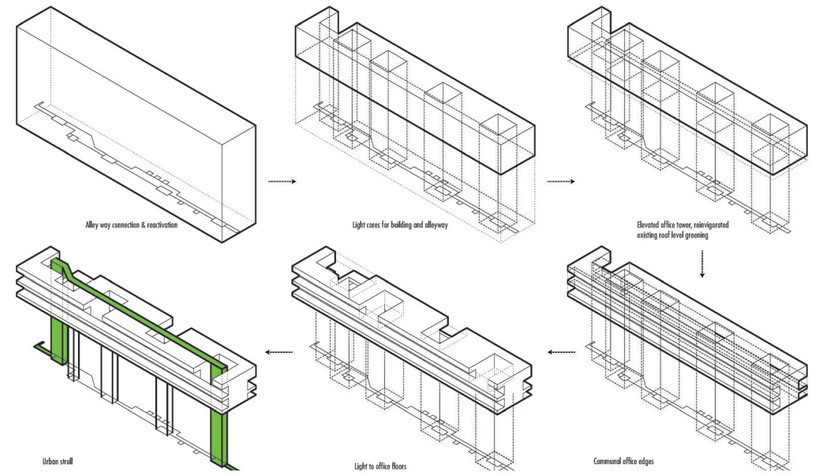
This project is a proposal for reactivating the alleyways between existing, residential podium towers of the North Point Lowlands by providing a public space for retail and recreational use. The alleyways are supplied with light and air through open cores and mechanical shafts that subsequently bring pedestrians up and into creative industry offices. Existing roof-tops of the neighboring point towers are reinvigorated with roof-level park spaces, which, in turn, create another level of public access to the city. Office spaces are organized in ways that promote collaboration through permeable spaces that interconnect different organizations, areas, and usages of creative industries within the building. Light penetrates the new tower to provide allow interior floor plates, existing roof-tops, and the alleyways below with ample access to light and air. The fin-like appendages explored in previous projects are used as a weather barrier.



(Left) Ground connections , balcony and weather barrier functions **[Fig. 7.19]**

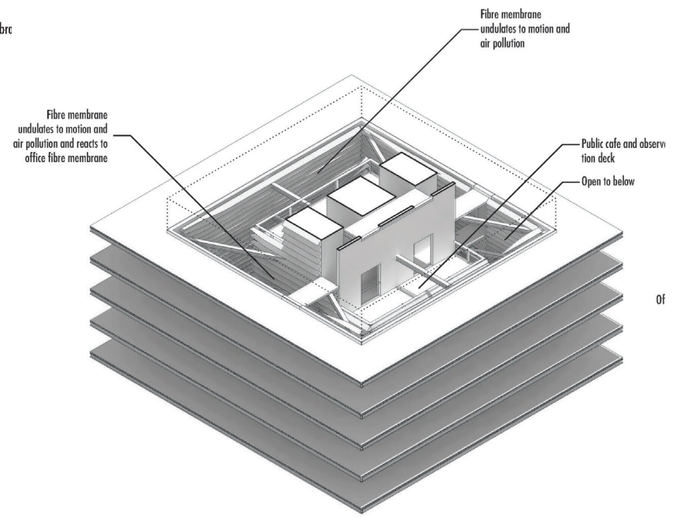
(Centre) Exploded core detail **[Fig. 7.20]**





[Fig. 7.21] (Above) Creative industry office massing parti development

[Fig. 7.22] (Below) Core and office connection

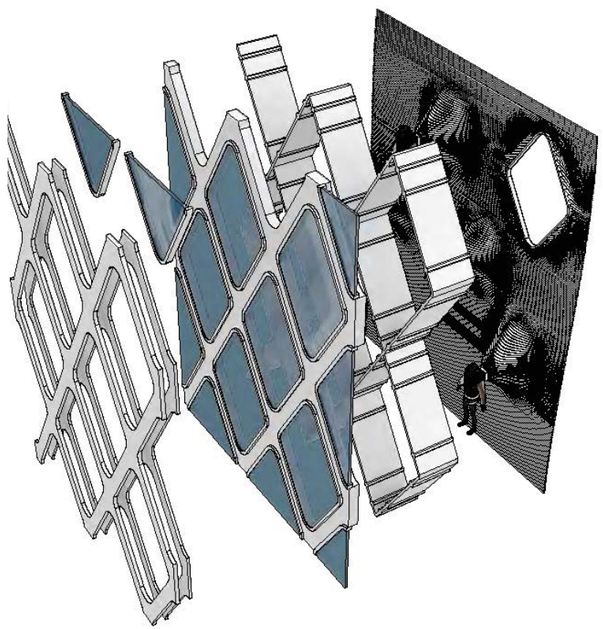


APPLIED FINS

The next scale of exploration occurs at the boundaries of buildings. These boundaries create buffers between conditioned and unconditioned spaces. Fin-like appendages encase the human body- and are then connected to physical building elements. A structural, light-frame diagrid encases work spaces. Cells positioned at the boundaries of the building act as air intake for the building while simultaneously housing a reinvigorated human body.

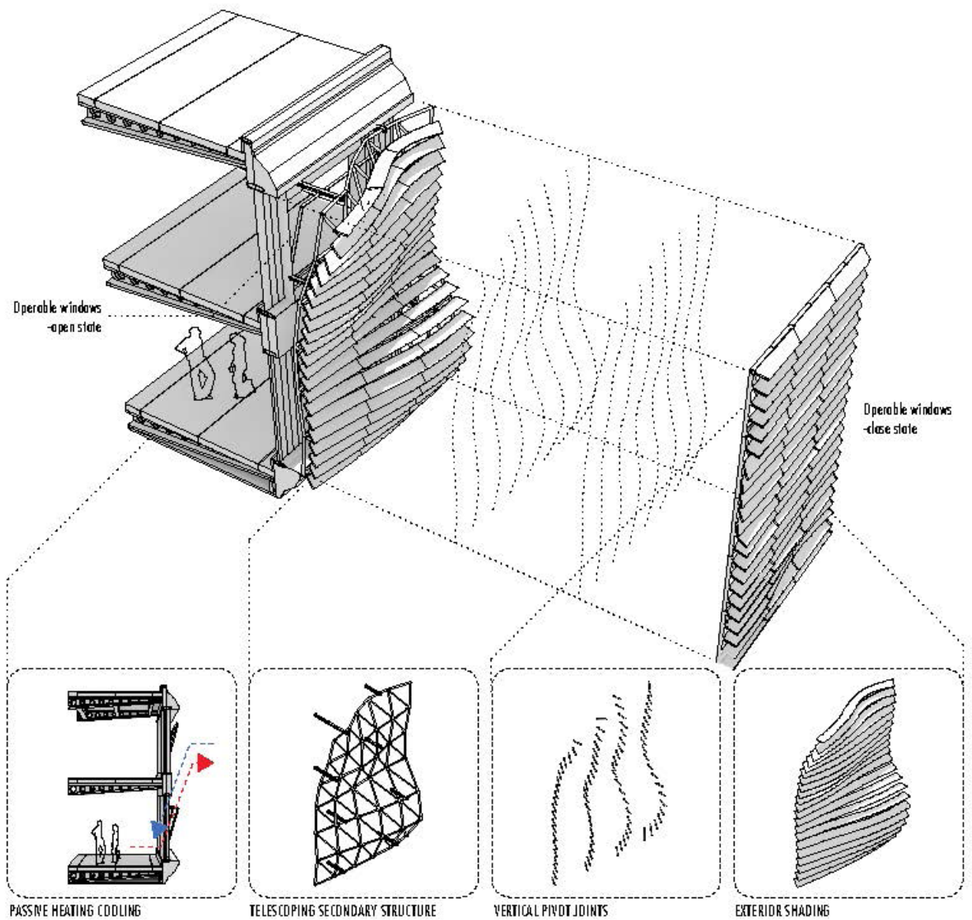
THE ATRIUM

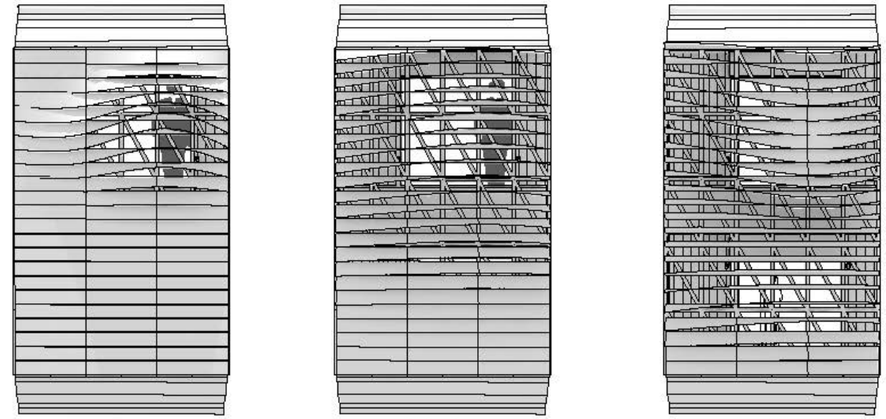
Beyond the boundaries of the building and into conditioned spaces, there is an atrium with similar fin-like appendages mentioned above. Composed of a telescoping frame, horizontal fins run throughout the assembly. The climate in this space adjusts to the spatial needs of individual groups of inhabitants by controlling air flow, as well as thermal and radiant energy.



(Top left) Cyborg cells at boundary of building [Fig. 7.23]

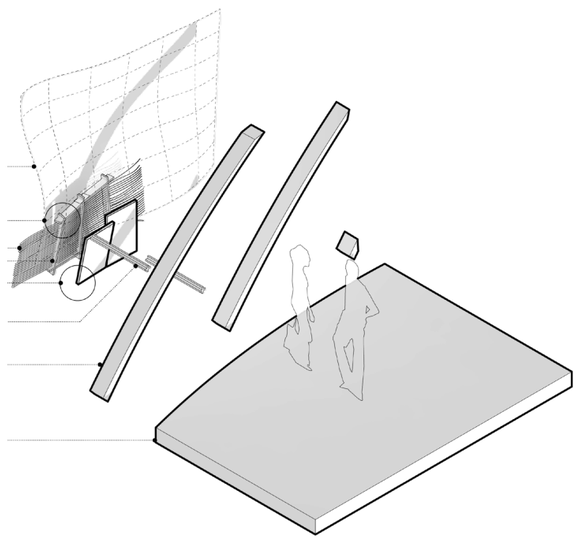
(Centre) Human comfort corresponding to visual form [Fig. 7.24]

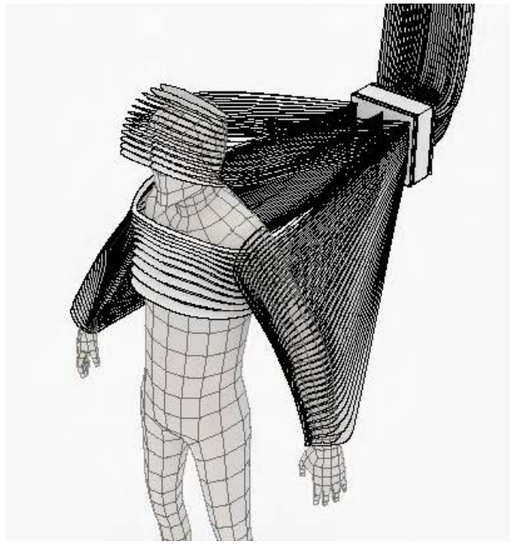




[Fig. 7.25] (Above) Human visual integration with facade

[Fig. 7.26] (Below) Facade integration with building structure

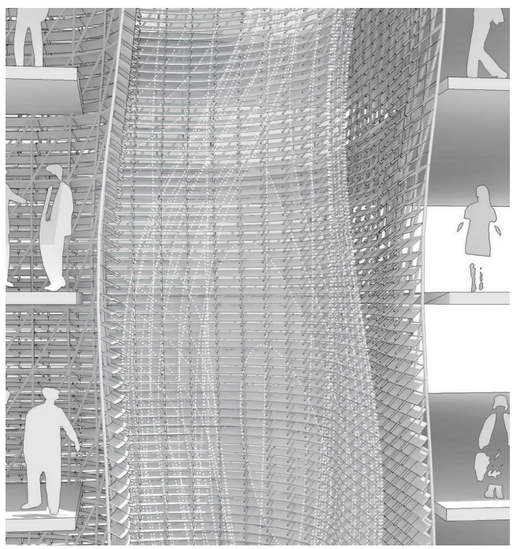


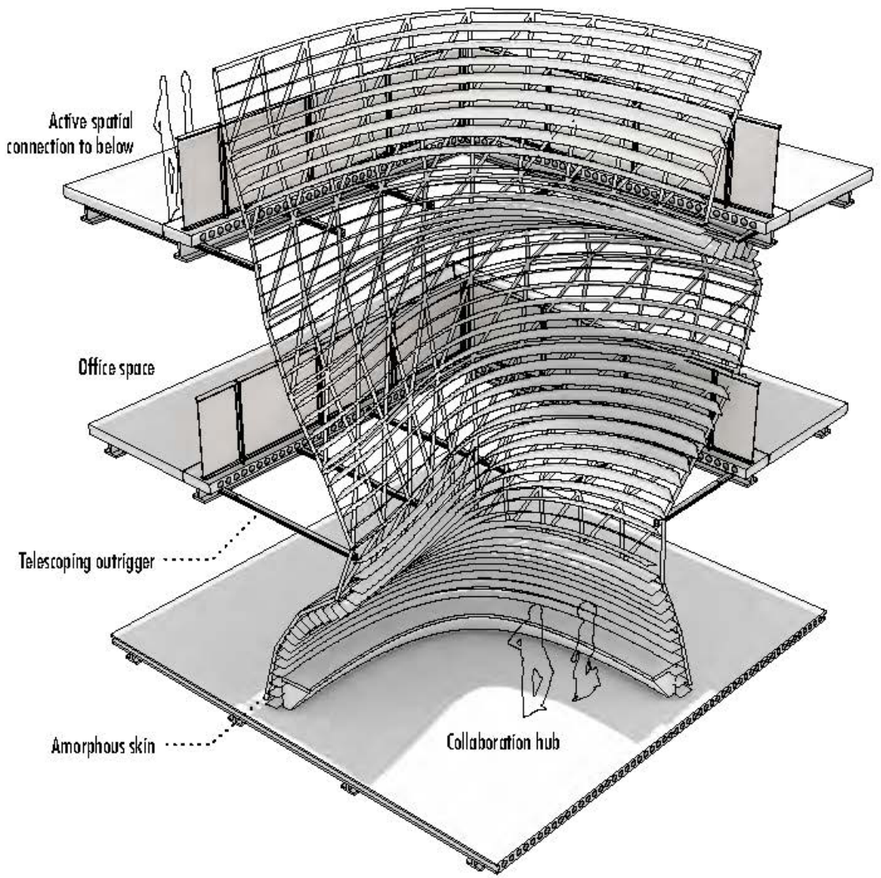


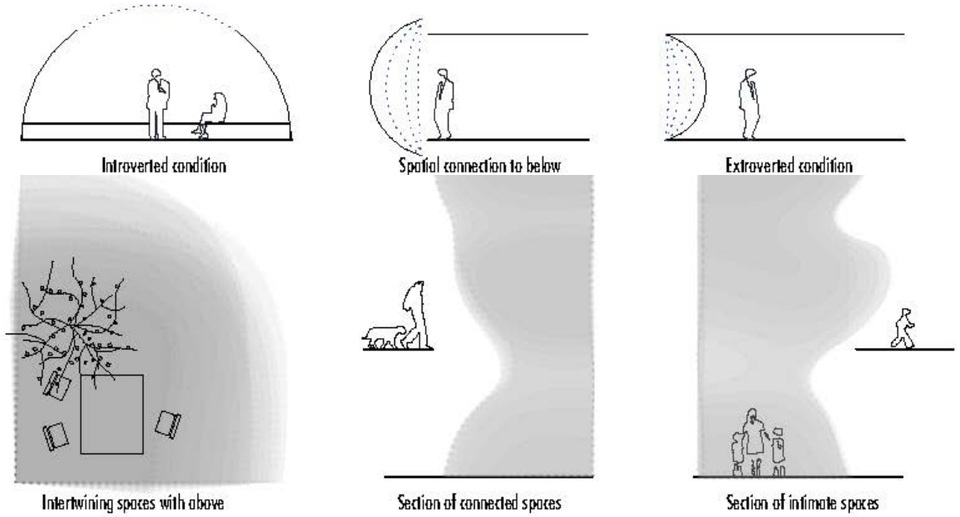
(Top left) Coupled human building axonometric [Fig. 7.27]

(Bottom left) Toxins are captured and water vapour is condensed [Fig. 7.28]

(Centre) Highly personalized spatially defined collaborative atrium space [Fig. 7.29]

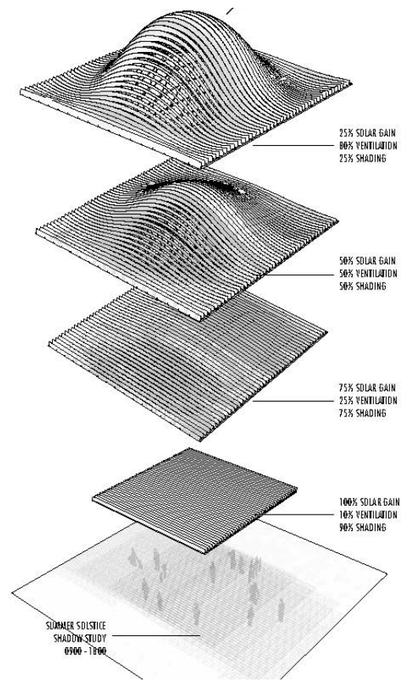


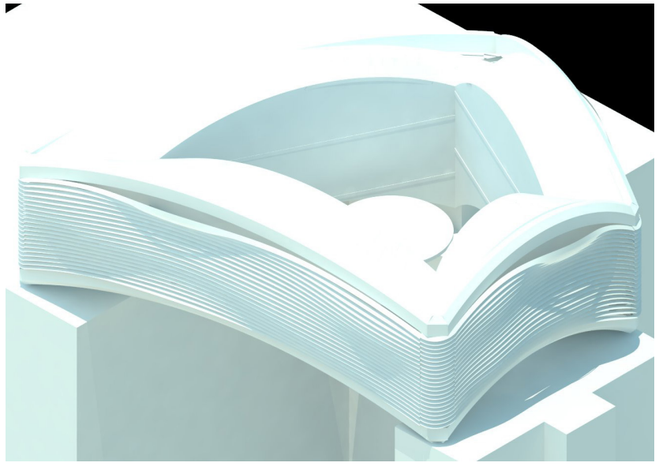




[Fig. 7.30] (Above) Gradients of spatial types

[Fig. 7.31] (Below) Canopy fins spatially reacting to regional climate





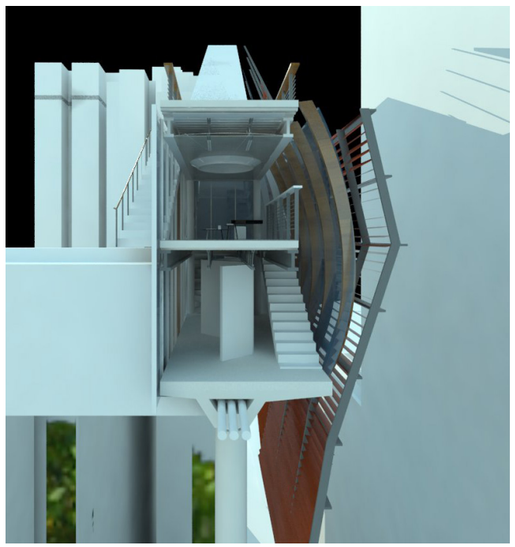
(Top left) Speculative roof-top building drawing vapour and purifying urban pollution. [Fig. 7.32]

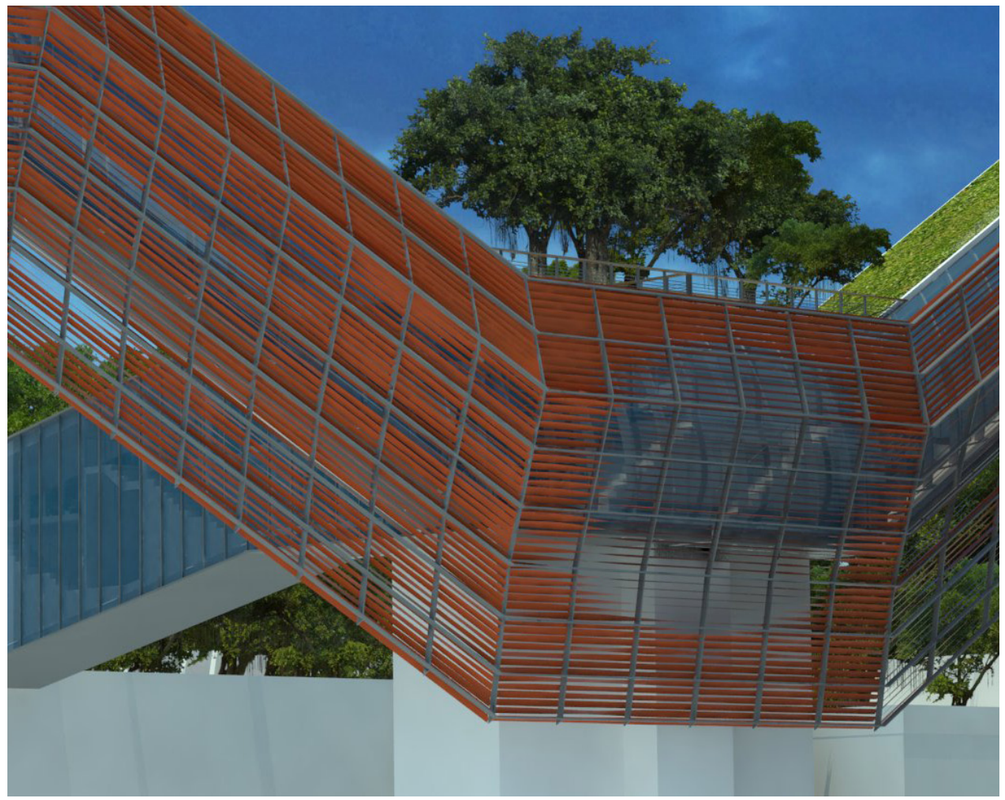
(Bottom left) Cross-section of rooftop apartment with facade membrane [Fig. 7.33]

(Centre) Speculative roof-top apartment rendering with facade membrane [Fig. 7.34]

CLOSING WORDS

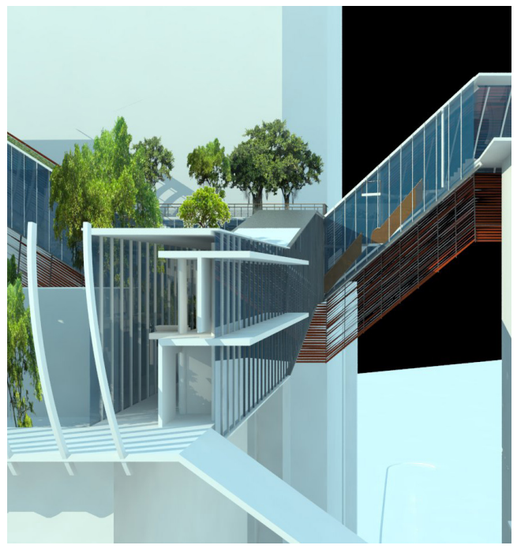
These speculative designs attempt at revealing a correlating human-architecture relationship. This is attributed to the design of a material with programmed functions and capabilities. They begin from the capabilities of it having embedded elegance, a material with multiple functions and hidden structural significance, like all natural materials. This transfixiation led to the scaled, multiplied application to the human body that is then brought into the realm of the built environment. These explorations proved to be a valuable creative process, used to propell the act of creating architecture into the realm of imagination with possibility to yield many solutions to our current predicament.





[Fig. 7.35] (Above) Interior rendering of roof-top apartment dwelling

[Fig. 7.36] (Below) Cross-section rendering of circulation between roof-top apartment dwellings



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